The Economic Impacts of Processing Based Intellectual Property Protection:
The Case of Red Lentils

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By

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Abstract

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Supervisors: Dr. R. S. Gray and Dr. E. T. Micheels

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Saskatchewan's lentil producers are positively impacted when their temporary competitive advantage in the industry, which in part is derived from high yielding Saskatchewan-bred lentil varieties, is eroded though ineffective intellectual property (IP) protection. The ineffective IP protection occurs due to the inconsistency in the enforcement of policies and laws across countries, making it difficult to protect IP when exporting products. Additionally, intellectual property protection of lentils is inefficient is when viable seeds are obtained by other countries through the export of whole seeds. This is because lentils are an open pollinated crop and intellectual property cannot be protected through hybrid seed technology. This is an issue because the Canadian red lentil (CRL) varieties have been bred for the Saskatchewan climate, but are well suited to grow in countries that have similar climates, and therefore are well adapted to large regions of Russia and Kazakhstan. The similarity in growing conditions, coupled with the lack of IP protection for the CRL varieties makes it possible for Russia and Kazakhstan to use imported Saskatchewan bred lentil varieties to grow in their lentil industry. When Russia and Kazakhstan grow the CRL varieties it directly competes with Saskatchewan's production in the world market, eroding the producer surplus of Saskatchewan producers. This thesis estimates the economic benefit to Canadian growers of restricting access to Canadian varieties through a value chain that genetically protects the CRL varieties by exporting only de-hulled red lentils.

A dynamic, multi-country, partial equilibrium model is used to estimate the effects de-hulling CRL varieties before export will have on the Canadian lentil industry. This model determines the effects that de-hulling CRL's will have on Canadian lentil producer's welfare by comparing the results from when there is *genetic protection (GP)* for the CRL varieties before they are export and then there is *no genetic protection (noGP)* for the CRL varieties.

In my thesis, I examine four potential scenarios for the future lentil production in Russia and Kazakhstan over the next twenty years. The four growth scenarios that are examined for

Russia and Kazakhstan's lentil industries range from *no convergence* to *full convergence*. *No convergence* is when Russia and Kazakhstan continue producing lentils with their 2011 lentil hectares until 2034. *Full convergence* is when both countries converge to the Canadian lentil industry's ratio of lentil hectares to spring wheat hectares.

The empirical model results show that producer surplus gained by Canadian lentil producers are increased when Canadian firms use *GP* to protect the intellectual property rights (IPR) of new CRL varieties. My results show that lentil prices in the global market will be modestly higher when there is *GP* for lentils versus when there is *noGP* for lentils over the next twenty years. The difference in the prices of the *noGP* case and the *GP* case gets larger as Russia and Kazakhstan go from *no convergence* to *full convergence*. The price impacts of *GP* in 2034 range from a $0.52 per tonne increase with no convergence to a $5.92 per tonne increase with full convergence. If the net processing margin is not increased, *GP* will produce a 2012 discounted price of $2.41 billion over the 2014-2034 period, suggesting only modest returns from *GP*. When all four convergence scenarios are evaluated and weighted by expected probabilities of occurrence, the estimated overall economic impact for Canadian lentil producers from 2014 to 2034 will be $47.12 million in additional producer surplus (PS), which is equal to an increased price of $3.41 per tonne. For this to be feasible the cost of de-hulling the lentils must be profitable to the processors at $3.41 per tonne or less.

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List of Abbreviations

AAFC - Agriculture and Agri-Food Canada

CDC - Crop Development Center

CPI - Consumer price index

CRL - Canadian red lentil

CSGA - Canadian Seed Growers Association

CWB - Canadian Wheat Board

FAO - Food and Agriculture Organization

GP - Genetic protection

IP - Intellectual property

IPR - Intellectual property rights

NoGP - No genetic protection

PS - Producer surplus

ROW - Rest of the world

SAFRR - Saskatchewan Agriculture, Food and Rural Revitalization

SPG - Saskatchewan Pulse Growers

TCE - transaction costs economies

US - United States

VRP - Variety Release Program

WGRF - Western Grains Research Foundation

1. Chapter One - Introduction

1.1 Problem Statement

Saskatchewan’s international competitive advantage in the lentil industry, which in part is derived from high yielding Saskatchewan bred lentil varieties, will be eroded without effective intellectual property (IP) protection. Unlike corn and canola, which are protected by hybrid seed technology, lentils and other open pollinated crops provide viable seed for other countries when they are exported as whole grains. In the case of red lentils, Canadian lentil varieties are well adapted to large regions of Russia and Kazakhstan. Given the lack of effective intellectual property rights (IPR) in these jurisdictions, Saskatchewan bred lentil varieties can be imported and grown in these jurisdictions. The foreign production from Saskatchewan varieties will directly compete with domestic production eroding Canadian producer’s competitive advantage. A proposed method to limit the foreign planting of elite Saskatchewan varieties is to create a value chain where lentils produced from these varieties are all de-hulled prior to export. This thesis estimates the economic benefit to Canadian growers of restricting access to Canadian varieties through a value chain that de-hulls all red lentil exports.

1.2 Background

There has been rapid growth in Canadian lentils developed over the last forty years. Lentils were initially grown by a few farmers as a cash crop during difficult economic times. Later, as research developed better varieties and agronomic practices improved, pulse crops became an integral part of longer rotations of zero tillage cropping systems. Today the Canadian lentil industry, almost exclusively located in Saskatchewan, is the world's largest lentil producer and dominates global lentil export markets (Pulse Canada, 2007). Much of the successful development of the Saskatchewan lentil industry can be attributed to the Saskatchewan Pulse Growers (SPG). The SPG is a check-off funded organization established in 1984 to grow and to help support the development of the pulse industry in Saskatchewan. The SPG entered into an agreement with the Crop Development Centre (CDC) to fund a pulse breeding program where the SPG would have royalty free control of all new pulse varieties developed by the CDC. The CDC's breeding programs have become a source of genetic advancement (Saskatchewan Pulse Growers, 2012b). This partnership has been very successful providing growers with a stream of new varieties that have significantly increased yields and reduced production costs over the past 30 years (Gray and Scott, 2003). These varieties and other innovations are part of the competitive advantage that has enabled Saskatchewan producers to expand production and become the dominant exporter of lentils in the world.

When Canadian lentils are exported as whole grains they could be purchased and used as seed in foreign countries. Given the rapid genetic advancement in lentil varieties created by the CDC Canadian varieties may perform better than locally available varieties, as compared to varieties bred elsewhere where similar agro-climatic conditions prevail. As will be described in more detail in Chapter Two, this scenario is already occurring in the more arid crop regions of Russia and Kazakhstan, a large land area with a potential for lentil production that is well suited to growing Canadian lentil varieties. If these regions develop a large lentil industry based on Canadian lentil varieties they will compete in export markets and reduce the Canadian lentil industry's competitive advantage.

The rate of erosion of the Canadian lentil industry's competitive advantage will depend on the size of the foreign industry and the rate of diffusion of Canadian varieties. Early adopters of the new varieties will enjoy higher profits from increased yields. Currently countries are able to obtain newly developed Canadian lentil varieties with superior genetics in the consumption market, because Canadian firms often export whole lentils, which are self-pollinating and self-replicating. As other countries grow the new Canadian lentil varieties the world supply of lentils increases, this leads to a lower world price of lentils, causing revenues and profits to decline. Not only do higher profits vanish for the early adopters when other countries adopt these new varieties, but the competitive advantage within the Canadian lentil industry is lost because the other countries have access and are able to use the newly developed varieties. The rate at which the lentil price will fall will depend on how fast the new Canadian lentil varieties are adopted by other countries.

Inhibiting or slowing down the transmission of CDC lentils to other countries would allow Canadian lentil producers to maintain a production advantage for a longer period of time, which would benefit lentil growers in Saskatchewan. A physical mechanism to prevent the leakage of the intellectual property (IP) of the new Canadian lentil varieties would be to ship only de-hulled lentils to the final markets, instead of as whole seeds. De-hulling the lentils provides a *genetic protection* (*GP)* that makes the seeds unable to germinate, meaning other countries are not able to erode Saskatchewan's competitive advantage. Preventing other countries from attaining Saskatchewan's valuable resource means that Saskatchewan lentil growers will be able to continue to maintain an international advantage due to superior genetics for a longer period of time. When the other countries do not have access to the lentil varieties, higher profits can be maintained.

1.3 Objective

The goal of this thesis is to quantify the potential economic benefits received by Canadian lentil producers when IP of new Canadian red lentil (CRL) varieties are protected through the process of de-hulling elite CRL's before export. De-hulling lentils will protect the IP of CRL varieties. A dynamic, multi-country, partial equilibrium model is used to estimate the effects de-hulling CRL varieties before export will have on the lentil industry. A number of scenarios are analyzed to consider the range of potential outcomes for the future lentil production of other countries utilizing CRL varieties for seed. The three specific objectives of this thesis are:

1. To develop two models that show the lentil industry from 2014 to 2034; one model that shows what happens when Canadian firms have *no genetic protection (noGP)* for newly developed CRL varieties, and another model that shows the lentil industry when Canadian firms protect the IP of newly developed CRL varieties through *genetic protection* (*GP*).
2. To calculate the economic impacts that occur in the world lentil industry when Canadian firms do not protect IP of their CRL varieties versus when Canadian firms protect IP of their CRL varieties through *GP*.
3. To calculate the expected value for the economic impact of Canadian firms when there is *noGP* for new CRL varieties versus when Canadian firms protect IP of their new CRL varieties through *GP* for 2014 to 2034 using weighted averages.

This thesis gives greater focus on the impacts of the Canadian lentil industry when looking at the impacts of *GP* for new CRL varieties before export, instead of the impacts that will occur to Russia and Kazakhstan's lentil industries.

1.4 Organisation of the Thesis

This thesis is organized into six chapters. Following the introduction, Chapter Two provides additional background information on the lentil industry in Canada and examines lentil exporting and importing countries. A review of the literature regarding the information on supply chains and how the Canadian lentil industry supply chain works is also found in Chapter Two. The third chapter examines the adoption theory and the innovation treadmill hypothesis, which provides the framework for the conceptual model. The conceptual framework which is used for the empirical model is explained in Chapter Three. In Chapter Four, the empirical model is described and is used to estimate the difference of Canadian firms using *noGP* for their newly developed red lentil varieties before export versus Canadian firms protecting IP of the newly developed red lentils though *GP*. Chapter Five estimates the impact of Canadian firms using *GP* to protect IP of red lentils. The results are examined and described in Chapter Five. Chapter Six is made up of the summary and identifies areas for further research.

2. Chapter Two - Industry Background and Literature Review

2.1 Introduction

This chapter provides an overview of the very successful development of Saskatchewan lentil industry, which grew from a non-existing industry in the 1960s to become the dominant supplier in the world market, and raises the important question of how this development can be sustained. Section 2.2 describes the growth of the Saskatchewan lentil industry. The global lentil industry is examined in Section 2.3. Section 2.4 considers the causes of growth in the Canadian lentil industry by looking at the research and development that has occurred. This section also draws from the value chain theory, because successful value chains lead to growth in an industry. Section 2.5 uses sustained competitive advantage theory to consider how competitive advantage can be sustained when facing Russia and Kazakhstan as potential competitors. Chapter Two is summarized in section 2.6.

2.2 Saskatchewan Lentil Industry

Although pulses are grown all around the world, and date back more than 20,000 years, they did not become economically important to western Canada until the 1970's when farmers began to diversify into lentils and peas. Farmers initially diversified because of the extremely low local grain prices and very limited Canadian Wheat Board (CWB) delivery quotas for wheat and barley. Due to the low wheat and barley returns, farmers experimented with new crops in order to generate revenue. Many Saskatchewan farmers found pulse crops to be good source of income in otherwise difficult times (Saskatchewan Pulse Growers, 2012a).

By the 1980s improved grain markets reduced the need for income diversification, but other factors were creating new forces for crop diversification. Summer fallow acreages declined and cropping rotations became longer. Growing pulse crops allowed for longer rotations, which helped improve the control of diseases and weeds and provided increased production for the crops. By the late 1980s, and especially during the 1990s, widespread technological change had begun to occur and more farmers were using a direct seeding method which eliminated tillage prior to seeding (Saskatchewan Pulse Growers, 2012a). Pulse crops fit very well into these cropping systems.

2.2.2 Lentils

Lentil production in Canada has been growing rapidly since they were first introduced and are continuing to increase in production today. The Food and Agriculture Organization (FAO) of the United Nations estimated that in 1975, Canada produced 300 tonnes of lentils (FAO STAT, 2012a). This number has significantly increased through the years (FAOSTAT, 2012a). In 1981 Statistics Canada estimated that Canada produced 56,000 tonnes of lentils. In 1990, the amount of lentils produced in Canada was 213,000 tonnes, and in 2010 the total amount of lentils produced grew to 1.9 million tonnes (Statistics Canada, 2012b). Canada's rapid increase in lentil production can be seen in Figure 2.1.

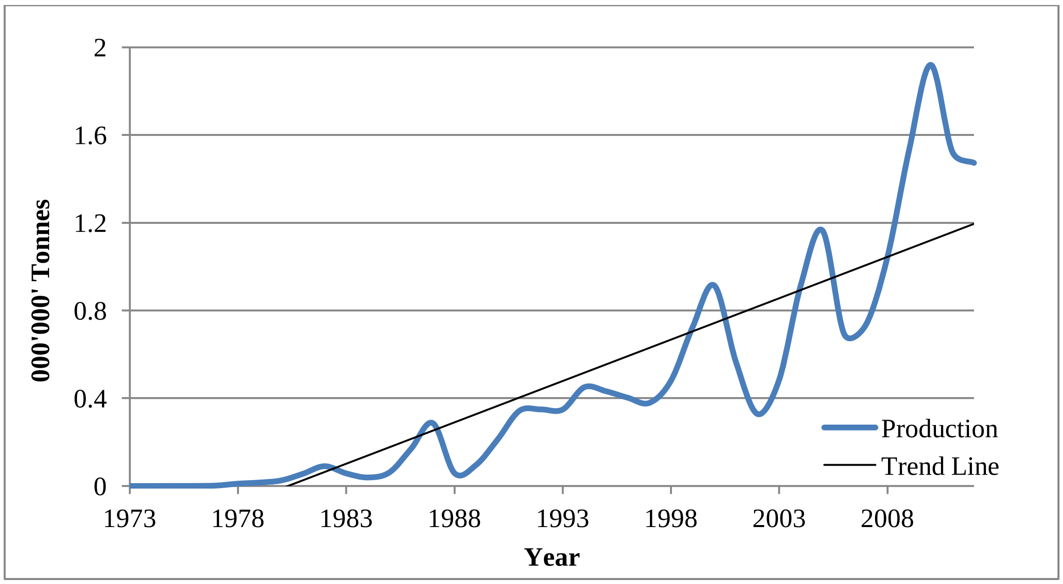

Figure 2.1 Canadian Lentil Production Trend, 1973-2012
Source: Statistics Canada, 2012b; FAOSTAT, 2012a

In Canada lentils are grown primarily in Saskatchewan (Saskatchewan Pulse Growers, 2012a; Pulse Canada, 2007). Saskatchewan is an ideal place for lentils because lentils are a cool season crop that requires some moisture stress. Lentils do well in countries with cooler climates or in countries that have winter growing seasons (Vandenberg and Risula, 2010). With the combination of a well-suited agro-climatic conditions and a well-funded, well-tailored research system, Saskatchewan dominates the Canadian lentil industry. Saskatchewan produces about 99 percent of the Canadian lentil crop (Saskatchewan Pulse Growers, 2012a; Pulse Canada, 2007).

Over time, the amount of green lentils produced in Saskatchewan has fallen as acreage has shifted towards red lentils. Some of the earliest breeding success was with green lentils.

Laird lentils, bred by Dr. Al Slinkard, became very popular and dominated the industry in the late 1980s (Agriculture and Agri-Food Canada, 2007). In the early 1990s, 75 percent of the lentils produced in Saskatchewan were green lentils and 25 percent were red lentils. By 2010 the total percentage of red lentils had increased to 50 percent of the province's production. The increase in red lentil varieties has been driven by three factors that have made red lentils increasingly popular with producers: lower green lentil prices, new higher yielding varieties of red lentils, and the development of Clearfield herbicide-tolerant varieties (McVicar et al., 2010).

2.3 The Global Market

2.3.1 Global Production

Global production of lentils has also been increasing in recent years, climbing from approximately 2.8 million tonnes in 2000 to 4.4 million tonnes in 2011 (McVicar et al., 2010). In 2011, the major lentil producing countries were Canada, Turkey, Australia, the US, Nepal, and Syria (FAOSTAT, 2012a). The major lentil producing countries production amount can be seen in Table 2.1.

Table 2.1 The Major Global Lentil Producing Countries, 2011

Country	Production 000'000' tonnes
Canada	1.50
India	0.94
Turkey	0.41
Australia	0.38
US	0.22
Nepal	0.21
Syria	0.11

Source: FAOSTAT, 2012a

India is the world's largest consumer of lentils and most of the lentils produced there are either consumed domestically or by neighbour countries (Saskatchewan Pulse Growers, 2012b). Lentil production has been increasing for Canada, Australia and the US and it is assumed that this trend will continue.

2.2.3 Price

The price of lentils is determined by the world lentil market and have generally trended downward over time (Agriculture and Agri-Food Canada, 2010). Figure 2.2 shows the Canadian dollar price of green and red lentils from 1971 to 2011, adjusted to 2012 dollars. The 2012 real dollar price for lentils had a huge price increase of about 350 percent from 1971 to 1977. After 1977 lentil prices continued to decline until about the 1990 where they stayed relatively constant, fluctuating between $800 to $400 per tonne. The overall inflation adjusted price for lentils from 1971 to 2011 has trended downwards, which can be seen in Figure 2.2 (FAOSTAT, 2012b). Between 2007 and 2008 the real dollar price of lentils increased, because India and Turkey, two large producers of lentils, faced a period of drought (Pulse Canada, 2007). Also lentil production in Turkey has been declining due to the changing agricultural structure of the country. Higher lentils prices were seen because India and Turkey are large producers in the world market and when those countries face periods of drought it decreased the global supply of lentils (Agriculture and Agri-Food Canada, 2010).

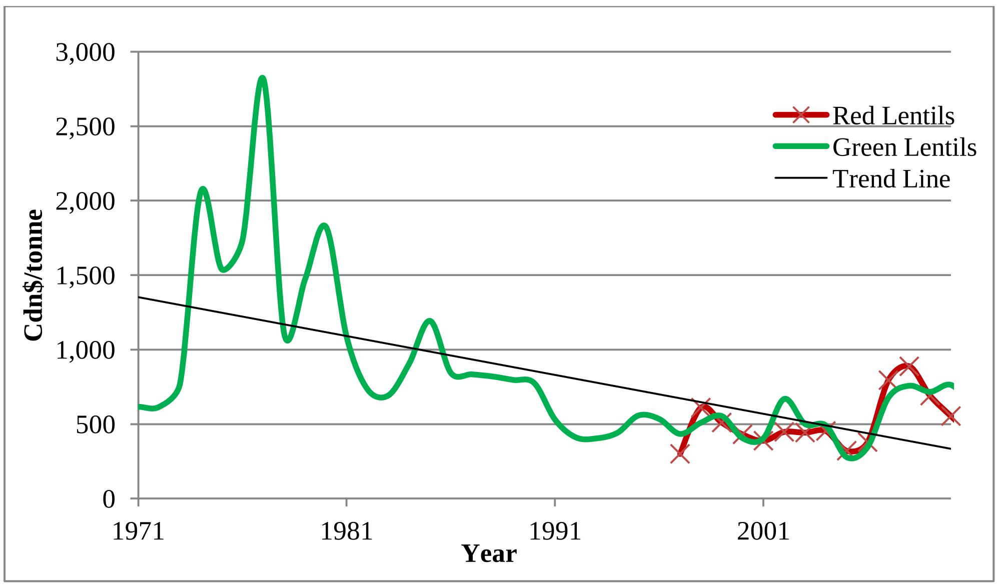

Figure 2.2 Canadian Average Price for Lentils, 1971-2010
Source: FAOSTAT, 2012b; FAOSTAT, 2012c; Morgan, 2012; Saskatchewan Agriculture and Food, 1990; Statistics Canada, 2012a.

2.3.2 Global Trade

Canada, Australia and the US are countries that export, producing more lentils then they consume (Vandenberg and Risula, 2010). Canada is a small domestic user of lentils and the worlds largest producer, allowing the country to dominate global exports. Canada only uses 15 percent of its lentil production as food, feed and seed, and exports the remaining 85 percent (Agriculture and Agri-Food Canada, 2001). The top exporting country in the world is Canada, followed by the US, Turkey, and Australia. Combined, they account for more than 90 percent of the worlds exports, as illustrated in Figure 2.3 (Agriculture and Agri-Food Canada, 2001; and FAOSTAT, 2011). In 2010 Canada exported about 1.18 million tonnes of lentils, the US exported 209,000 tonnes of lentils, Turkey exported 195,000 tonnes of lentils and Australia exported 138,000 tonnes of lentils. There are many countries which import lentils, the major importing countries are Turkey, India, Bangladesh, the United Arab Emirates, Sir Lanka, Egypt, Pakistan, Algeria, Colombia and Spain (McVicar et al., 2010; Vandenberg and Risula, 2010; and FAOSTAT, 2011). These countries are not able to produce the amount of lentils they consume therefore they must import lentils. Turkey is able to be a large exporter and the number one importer of lentil because they re-export lentils.

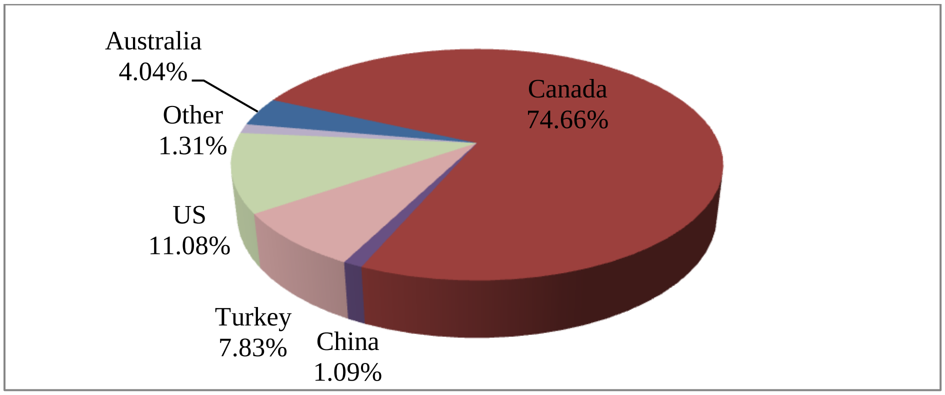

Figure 2.3 Lentil Exporters for 2009
Source: FAOSTAT, 2011

Over time, the import demand for red lentils has trended upward, as importing countries in the Middle East and Asia have generally increased their consumption of red lentils (Agriculture and Agri-Food Canada, 2001). Turkey is an important source of demand instability. When Turkey faces years of drought they fail to be a large exporter of lentils and import red lentils from Canada. These droughts provide significant short run opportunities for the Canadian red lentil industry (Vandenberg and Risula, 2010).

2.3.3 Canadian Lentil Exports

Canada exports its lentils to 120 countries throughout the world; however 50 percent of production goes to three countries: India, Turkey and Bangladesh (Agriculture and Agri-Food Canada, 2001). Canada's main exporters of red lentils are India, Turkey, Bangladesh, Egypt, United Arab Emirates, Saudi Arabia, Pakistan, Sir Lanka, and the Mediterranean regions (McVicar et al., 2010; and Agriculture and Agri-Food Canada, 2001).

Lentil exports from Canada are currently shipped primarily in the form of whole seeds. Some lentil exports are cleaned, sorted and shipped in marine containers, while other exports are bulk shipments. Whole, whole and de-hulled, and de-hulled and split lentils are all different forms of lentils desired by the importers of Canadian lentils, but preferences do vary. Because most final consumers prefer their lentils de-hulled, imported Canadian lentils are typically de-hulled after they enter the country. De-hulling red lentils before export could potentially be a new market for the exports of Canadian red lentils (Saskatchewan Pulse Growers, 2012c).

De-hulling red lentils is a potential value-added process for processing plants in Canada (Saskatchewan Pulse Growers, 2012c; Alliance Grain Traders, 2011). Most pulse plants are currently engaged in sorting and cleaning lentils. Buyers are willing to pay more for higher quality, clean product and the off-grade[1] lentils sorted out during cleaning go for feed lentils. The result is an increase in overall value. De-hulling the lentils is an additional process, where the external hull of the seed is separated from its interior. Consumers buy the de-hulled lentils and use them in range of dishes, while the seed coats are typically used in the feed market. While most lentils are not de-hulled in Canada, one of the largest splitting processor of lentils in the world is Saskatchewan based Alliance Grain Traders (Alliance Grain Traders, 2011). Depending on the cost of processing and the premiums paid for de-hulled lentils, de-hulling represents a potential value added opportunity for lentils.

2.4 Growth in the Canadian Lentil Industry

This section explores why the lentil industry has been able to successfully grow from nonexistence to producing 1.5 million tonnes of lentils annually in less than 40 years.

[1] Off-grade lentils are the lentils that are sprouting, broken, a smaller size and light weight

2.4.1 Research and Development

In Saskatchewan, a new organization was established in 1984 to help support the development of the pulse industry. This organization was initially called the Saskatchewan Pulse Development Board and was later renamed as the Saskatchewan Pulse Growers (SPG). The organization was established by a vote of a small number of pulse growers in Saskatchewan. As a Development Board the 0.5 percent levy was non-refundable. The SPG continues to support the development of the pulse industry in Saskatchewan by investing in research and development, market development, extension and communications, variety release programs and general operations (Gray and Scott, 2003). In Saskatchewan, SPG represents 18,000 pulse growers (Saskatchewan Pulse Growers, 2012c). The SPG is funded by all pulse growers in Saskatchewan, who are required by law to participate in the check-off program. Other organizations that have helped fund pulse research include: Saskatchewan Agriculture, Food and Rural Revitalization (SAFRR), Agriculture and Agri-Food Canada (AAFC), and the Western Grains Research Foundation (WGRF). In 1997, SPG and the Crop Development Center (CDC) formed an agreement whereby the SPG would support the pulse breeding program of the CDC in exchange for royalty-free control of all new pulse varieties developed by the CDC (Gray and Scott, 2003). This agreement allows for an increase in supply of pulse varieties and an improved quality of Canadian pulses (Saskatchewan Pulse Growers, 2012b). The research and development in the lentil industry has played a large role in the remarkable growth in the Canadian lentil sector.

The Variety Release Program (VRP) is a program that has helped in the growth of the lentil industry in Canada. Formed in 1997, the VRP allows producers to have a steady supply of the new and improved pulse varieties quickly. The VRP is in charge of distributing new varieties of pulses to selected status pulse growers in Saskatchewan and Alberta. The VRP has encouraged the pulse sector to grow rapidly because of its ability to have the new varieties that were developed ready for the producers to sow (Saskatchewan Pulse Growers, 2012b).

An association that is important to pulse growers is Pulse Canada, established in 1997 by Canada's pulse growers and the Canadian Seed Growers Association (CSGA). Pulse Canada is partnered with pulse growers and members of the pulse trade in Canada. Pulse Canada works to expand the pulse export market by conducting promotional and servicing activities, exploring potential markets and increasing research for pulses on a national and international level. They provide market information and coordination of the pulse research on national and international levels. Pulse Canada also acts on international market access and trade barrier issues, where they are the voice for the Canadian pulse industry (Saskatchewan Pulse Growers, 2012b; Pulse Canada, 2007).

2.4.2 Value Chain

Many firms have been moving towards value chains, which can help an industry grow and be successful. A value chain is an integrated process where firms work together to move products through the stages of production by taking raw materials and converting them into a final product that is ready for consumption. Traditionally a value chain will be characterized by a forward flow of material and have a backwards flow of information (Beamon, 1998). Each stage is represented as a different chain in the production process (Kennett et al., 1998). Many companies have been moving away from spot markets and moving towards closer vertically co-ordinated value chains. Vertical co-ordination is the process of minimizing transaction costs through the value chain. When companies move towards vertically co-ordinated value chains, it means that they will be moving to a market that utilizes concepts such as strategic alliances, joint ventures, contracts and franchising. The move towards value chains has been occurring due to technological, regulatory and financial reasons, as well as changing consumer preferences.

When buyers and sellers conduct transactions there is a cost that occurs. Those costs are called transaction costs and they occur because of information asymmetry, bounded rationality and opportunism behaviour (Hobbs and Young, 2000). Information asymmetry occurs when the parties involved do not have the same information. Bounded rationality is when people make the best decision they can with the information they have. Bounded rationality occurs because people cannot determine how the market will change and evolve in the future, which leads to people having to make decisions based on the information they know now. Opportunism behaviour is when someone seeks for one's self-interests using deceitful behaviour. Opportunism behaviour leads to lack of trust of others, which results in an unwillingness to trust and rely on others (Williamson, 1979). By understanding transaction costs economies (TCE) it is understood why firms are moving towards closer vertical co-ordinated value chains (Hobbs and Young, 2000).

Transaction costs that arise *ex ante* are search costs and they include, but are not limited to, factors such as the time and resources required to identify suitable trading partners, gathering price information, and specifying or identifying quality of the products. Costs that are occurred during the transaction are called negotiation costs; they may include the costs of determining the contractual terms, paying agent or middleman fees, retaining the services of a lawyer. Transaction costs that arise *ex post* to a transaction are the monitoring and enforcement costs of ensuring all terms and agreements are followed through (Hobbs and Young, 2000). There has been a growing trend to have closer relationships in value chains because of increasing transaction costs for search, negotiation, and monitoring costs associated with using the market for agriculture products. Closer vertical co-ordination occurs to reduce or eliminate transaction costs in the supply chain.

To have a profitable value chain there are five fundamental principles to follow: (1) specify value, (2) identify the value stream, (3) ensure continuous flow, (4) govern production through pull, and (5) strive for perfection (King and Venturini, 2005). Specify value is when a firm understands the value the product offers the end consumer. Identifying the value stream is when a firm knows and understands the entire stages in the value chain from start to finish, and the value that each stage brings to the end customer. This includes not only the activities performed by one firm but all the activities performed by all the firms in the value chain. Ensuring continuous flow is making sure the value stream is operating at a pace in which they can keep a steady continuous flow of product instead of producing batches of product. For agriculture products, grain storage can be used to maintain a continuous flow because grain is a seasonal good. Governing production through pull is when production is not produced until there is a demand for the good from the customer. This eliminates inventory build ups and large price swings. To strive for protection a firm should have continuous incremental improvements in their products and processes. By always making small improvements it will ensure the value stream has a minimal amount of defects at each of the stages, which will reduce the need for costly repairs and replacements of broken or defective parts. For all those fundamental principles to make a value chain successful at all the stages there must be high levels of information sharing (King and Venturini, 2005).

2.4.2.1 Lentil Value Chain

The value chain of the Canadian lentil industry is well co-ordinated, which has helped in the success of the remarkable growth and development of the industry. The lentil value chain begins with the Saskatchewan Pulse Growers (SPG). The lentil value chain is shown in Figure

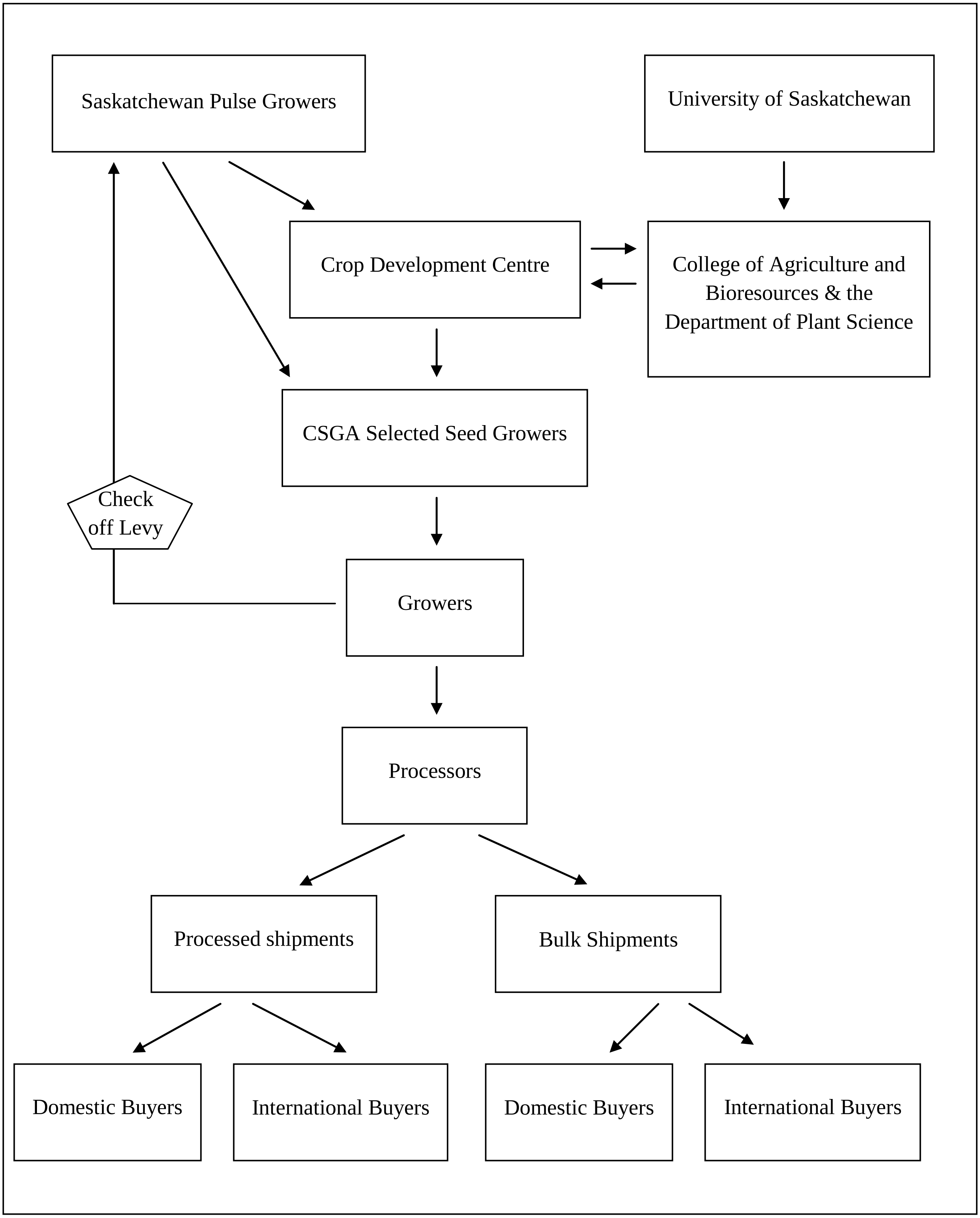

Figure 2.4 The Lentil Supply Chain
Source: McDonald, 2013.

2.4. The SPG receives levies from all commercial sales of pulse crops in Saskatchewan paid by the pulse growers (Gray and Scott, 2003). The check-off levies that are collected by the SPG go into investments in research and development, market promotions, communications and general operations of the organization. In the second stage of the lentil value chain is the Crop Development Centre (CDC). The CDC section of the value chain is where new varieties are developed. The CDC works closely with the Department of Plant Sciences and the College of Agriculture and Bioresources at the University of Saskatchewan. This stage is also where the new varieties are licensed to the SPG for commercialization (McDonald, 2013). The Canadian Seed Growers Association (CSGA) and the selected seed growers are the third stage in the lentil value chain. In this stage the breeder seed will be increased in order to make the seed available for the selected seed growers. Once the varieties are increased the seed is certified by the CSGA. CSGA growers will produce the certified seed and will sell the seed to farmers for their commercial farm operations. The fourth stage is the growers. The growers are the farmers who purchase the seed from the CSGA, and they will produce and harvest the lentils. Growers will sell their harvested seeds to the next stage of the chain which is the processors. Processors are the fifth stage of the lentil value chain; at this stage lentils are either processed and shipped or shipped in bulk unprocessed to domestic or international buyers (McDonald, 2013). This well co-ordinated value chain has allowed the lentil industry to grow to the remarkable size it is today.

2.4.3 Yields

The research and development that takes place in the lentil industry and the lentil value chain has allowed the Canadian lentil industry to thrive. The new lentil varieties that have been developed through research and development show this growth. The research and development could not have happen if it were not for the well co-ordinated lentil value chain.

Throughout the years there have been many different types of lentils that have been developed in order to improve the yield potential (Gray and Scott, 2003). Figure 2.5 shows that lentil varieties have had drastic yield increases throughout the years when compared to wheat yields. In this thesis, when examining lentil yields, wheat will be used to compare how lentil yields have changed over time. Wheat is used because it is the largest crop grown in Canada (FAOSTAT, 2012a).

Green lentil varieties were grown in the 1980s and when new varieties were developed, lentil yields increased. Green lentil yields have been increasing from 1984 to 2012. Lentil yields in this thesis are in an index, and the base of the index is the lentil variety Laird. In 1984 the average yearly green lentil yield index was 104 and in 2011 the yield index increased to 125. In 1996 the red lentil varieties became available to growing in Canada. Red lentil yields have been steadily increasing since 1996 to 2002. In 1996 the average yearly red lentil yield index was 98, and this yield index has been increasing and in 2011 the yield index is at 142. When comparing lentil yields to wheat yields, Figure 2.5 shows that lentils have increased at a faster rate than wheat. Wheat yields in this thesis are in an index; the base of the index is the wheat variety Manitou. In 1984 wheat yield index was 101 and throughout the years they slowly rose to 118 by 2011. This is slightly smaller than the green lentils yield index and considerably smaller then the red lentil yield index (SaskSeed Guide, 1984-2012). Figure 2.5 shows that research and development has increased the production of lentils through improving the yields, which has grown the Canadian lentil industry.

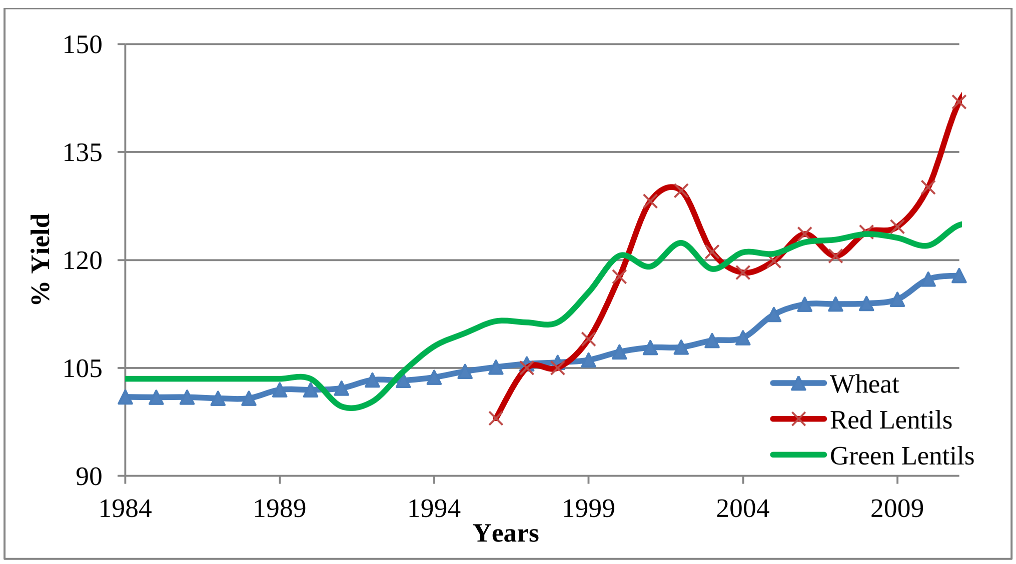

Figure 2.5 Canadian Average Lentil and Wheat Index Yields, 1984-2011
Source: SaskSeed Guide, 1984-2012

Research and development of new varieties that have occurred in the pulse industry has positively affected the lentil producers. It is estimated that from 1984 to 2012, for every dollar growers paid into the check-off program, pulse producers received an average of $15.82 back in producer surplus. From 1984 to 2012, pulse growers paid about 33.79 million dollars into the check-off program, which means that growers received about 534.8 million dollars' worth of producer surplus (Gray et al. 2008).

2.5 Sustained Competitive Advantage

Earning profits by creating and sustaining a competitive advantage is a firm's main goal in an industry (Lawson, et al., 2012). A competitive advantage in an industry is when a firm has a process, method, or information access to certain resources that others do not have, which allows them to have increased profits or desired products. A firm has a competitive advantage when it is implementing a strategy that creates value which is not simultaneously being implemented by competitors. A sustainable competitive advantage is when the firm has obtained a competitive advantage and it cannot be duplicated by competitors or potential competitors. A competitive advantage can be developed through trade secrets, access to limited natural resources, unique equipment, workers, environment, location, etc (Barney, 1991). Managers will try to provide a firm a way to have a sustainable competitive advantage and superior returns to capital by identifying, developing, protecting and deploying resources and capabilities of the firm.

Competitive advantages are obtained through a firm's resources. A firm's resources are the factors that are owned and controlled by the firm, which allow the firm to develop and implement strategies that improve efficiency and effectiveness. A firm's resources are the entire firm's assets, capabilities, organizational processes, attributes, information, knowledge, etc. (Barney, 1991; Amit and Schoemaker, 1993). The firm's resources are then used by combining the firm's assets and mechanisms to make products and services (Amit and Schoemaker, 1993). A firm's resources are used to implement their strategies; if the resources are value-creating strategies then they are strengths to the firm (Barney, 1991). When firms in an industry have homogenous resource bundles and production, it is not possible for a firm to conceive and implement a strategy that the other competing firms cannot replicate (Barney, 1991). A resource-based view looks at a firm as a collection of resources. Resources may allow firms to have a competitive advantage because some resources are heterogeneous from other firms (Peteraf, 1993). A firm's resources determine a firm's competitive position and their competitive advantages in an industry (Chen, 1996).

For a firm's resources to hold potential to create a sustained competitive advantage it must have four attributes. It should be: (1) valuable, (2) rare, (3) imperfectly imitable, and (4) have no substitutes. For a resource to be valuable in a firm's environment it must be able to exploit opportunities and/or neutralize threats (Barney, 1991). An example of a valuable resource would be those that are more efficient or are somehow superior to other available resources, because they will allow a firm to produce more economically and better satisfy customer needs (Peteraf, 1993). A rare resource will not be accessible to competitors or potential competitors because of the limited supply or availability of the resource. An imperfectly imitable resource cannot be copied or followed (Barney, 1991). If a resource is imitated it can be copied and others will benefit from the copied resource (Peteraf, 1993). For a resource to have no substitutes, there must be no strategically equivalent substitutes that have value, are rare and imperfectly imitable (Barney, 1991). If a resource is substitutable it will be more elastic and profits will be reduced (Peteraf, 1993). Resources that contain the four attributes described above will have the potential to creating a sustainable competitive advantage.

Isolating mechanisms help firms have a competitive advantage and maintain a sustained competitive advantage. An isolating mechanism will slow the process of imitation and force competitors to make a substitute or their own equivalent. This is done by making the resource imperfectly mobile. Some categories of isolating mechanisms are: knowledge protection, technological capabilities, market-based assets and the first-mover advantage. Knowledge protection is a way for a company to protect their intellectual property rights (IPR) or to prevent knowledge spillovers, and can be done through patents and trade secrets. Technological capabilities for a firm are the firm-specific knowledge and their complex routines which are unique to that firm, and which act as a barrier against imitation. Market-based assets are a way for a company to be recognized by the public; examples of this are brand names, market capabilities and distribution systems (Lawson, et al., 2012). The first-mover advantage allows a company to enter the market first, allowing the firm to build customer loyalty, access distribution channels and develop a positive reputation, gain access to geographic space, technology space and customer perceptual space before other competing firms. This implies that the firm that implemented the strategy would have had some insight on the opportunities of the implementation of the strategies which would mean that firms were heterogeneous (Barney, 1991). A firm's heterogeneity and performance differences are contributors to causal ambiguities arising in knowledge, social complexity and assets that are highly specific to that firm (Lawson, et al., 2012). Causal ambiguities arise when a firm does not understand why or how they have a sustained competitive advantage (Peteraf, 1993). Not knowing how or what to imitate makes it hard for competitors to copy or steal the resources. This is why sustained competitive advantage can be obtained when there is an isolating mechanism.

The Saskatchewan lentil industry's greatest resource is the ability of the producers to fund and develop a very effective breeding system for lentils, which allows them to produce superior genetics. The Saskatchewan lentil industry's greatest resource is imitable. Other countries could decide to move towards a similar industry as the Canadian's lentil industry, which would give them the tools to fund and develop effective breeding system. Canada has been growing there lentil industry for the last thirty years and it will not be easily imitable because it will take time for other countries to gain the knowledge and expertise that has been obtained by Canada. The superior genetics gives the Saskatchewan pulse industry a competitive advantage because it allows new varieties with improved yields to be produced. The new varieties not only have higher yields but they are suited to the growing conditions of Saskatchewan. For most countries, the Saskatchewan developed lentil varieties will not have optimal traits because of different climates, which do not allow the varieties to produce to their maximum potential. Two countries that have similar growing seasons as Saskatchewan are Russia and Kazakhstan. Ukraine's similar growing season does not make them ideal candidates to compete with Canada in the lentil industry. Profitable alternative to pulses and pulse yields being relatively small compared to spring wheat yields, makes pulse growth in Ukraine unforeseeable in the near future. Russia and Kazakhstan do not currently compete with Canada in the lentil market but they may have the potential to compete in the future. Russia and Kazakhstan are in the process of developing their pulse industry and once established they could be a potential threat[2] to the Canadian lentil market if they were able to attain the superior lentils that were developed by the Saskatchewan lentil industry.

2.5.1 Potential Competitors

Russia and Kazakhstan are not big players in the lentil industry as they have just begun to diversify into pulse crops (Boersch et al., 2012). The FAO (2012a) of the United Nations estimated that in 1992 Russia produced 7,060 tonnes of lentils. Russian lentil production has fluctuated a bit but has remained fairly constant until 2011, when production increased to 33,450 tonnes of lentils. Russian lentil production can be seen in Figure 2.6 (FAOSTAT, 2012a).

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[2] Russia and Kazakhstan are potential threats to the Canadian lentil industry in the lentil industry because they are located close to countries that import lentils.

Despite industry reports Kazakhstan has exported lentils in small containers, the amount of lentils that Kazakhstan has exported was not reported and therefore is unknown. It is anticipated that in ten years Russia will increase their pulse production by about 40 percent and Kazakhstan will increase their pulse production by about 133 percent (Boersch et al., 2012).

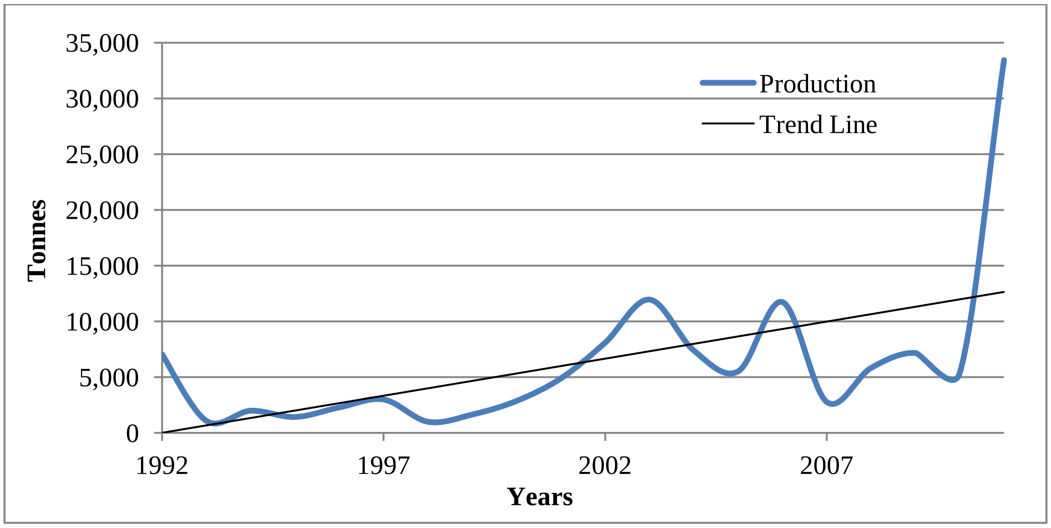

Figure 2.6 Lentil Production Trend for Russia, 1992-2011
Source: FAOSTAT, 2012a

Before Russia and Kazakhstan can be competitors in the lentil market they must take care of the issues that prevent them from expanding their lentil industry. The major constraints Russia and Kazakhstan face is that there is a limited amount of rail capacity for grain. In Russia, poor railway logistics and coordination make it difficult for Russia to get grain to port. The poor conditions of rail cars and grain handling facilities at the rail-side make rail transport a problem. Kazakhstan has limited availability of grain railcars to transport grain, because they use the same rail as Russia which forces Kazakhstan to compete for railcars with Russia. When Russia has a good year for grain there are less railcars available for grain produced in Kazakhstan. Due to limited access to railcars and ports, and because Kazakhstan is landlocked, they have high transportation costs for grains. The problems of the railway prevent Russia and Kazakhstan from being able to transport grain, which limits their ability to become threats in the lentil industry unless they can fix these issues, or find a different way to transport grain (Boersch et al., 2012).

Once Russia and Kazakhstan have fixed their transportation problems, they will have resources that are unattainable to Canada which will give Russia and Kazakhstan a competitive advantage. The establishment of rail and grain handling facilities at the rail-side in Kazakhstan and Russia is continuing to grow. This leads to access into neighbouring countries and allows new trade routes to be formed with Turkey, Pakistan and China. When Russia and Kazakhstan establish trade routes with Turkey, Pakistan and China they will become a huge competitor in the lentil industry and a threat to the Canadian lentil exporting market. The Black Sea is another form of transportation that Russia has access to and is a resource that gives Russia an advantage over Canada. For example, when Canada ships from Vancouver, BC to India it takes 11to 16 days longer compared to shipments that originate from the Black Sea. When comparing Canada and Russia shipments to China, the difference is 9 to 11 days longer for Canada. Kazakhstan's advantage is that they have low production costs. A huge competitive advantage for Russia and Kazakhstan will be gained when they have reduced their transportation problems (Boersch et al., 2012).

Russia and Kazakhstan's competitive advantage is that they are located near the countries that import lentils, while Canada's competitive advantage is their ability to make new lentil varieties that have higher yields. Location of a market is essential (Chen, 1996) and this cannot be attained by Canada, so therefore when competing with Canada this is a large competitive advantage for Russia and Kazakhstan. Canada's new lentil varieties are not considered a sustainable competitive advantage because the seeds that will be exported are static genetics of the progeny. This means that Russia and Kazakhstan will have access to the superior genetics when the seed from the new varieties which are exported. Russia and Kazakhstan could use the new Canadian red lentil (CRL) varieties and gain competitive positioning, while eroding Canada's competitive advantage.

Some companies protect their intellectual property (IP) though intellectual property rights (IPR). Intellectual property rights (IPR) are legal mechanisms that protects the property of an individual's innovation and creative activity or information from being copied and prevents it from being unauthorized use (Garmon, 2002). IPR are often protected by patents, trademarks, copyrights, trade secrets (Garmon, 2002; Carpenter, 2005). Having IPR to protect an industry's technical advances, research investments and capital expenditures is becoming increasingly important because companies are putting significant resources into innovations and technology in order to stay competitive and stay in the market. A company's intellectual capital is one of the most valuable assets as it allows companies to have advantages in a competitive market (Carpenter, 2005). IPRs are important to an industry because they play a critical role in economic growth and development by encouraging companies to invest in research and development (Garmon, 2002).

To prevent the erosion of the Canadian competitive advantage, a way to protect the IP of the CRL varieties is required. The IPR of the new red lentils varieties are licensed and controlled by the SPG (Gray and Scott, 2003). Policies and laws are not consistently enforced across countries, which makes it difficult to protect IP when exporting your product (Garmon, 2002). Countries do not have the same laws and regulations, so the leakage of IPR's occurs (Fang, and Si, 2011). Having different laws and regulations for the protection of IP across countries allows other countries to copy the new lentils varieties without incurring the costs required to develop these new varieties. Intellectual property rights (IPR) are difficult to obtain in most plants. Hybrid protection is used to protect IPR of some plants such as canola. Hybrid plants are sterile and seed cannot be replanted from year to year, which protects IPR for all hybrids. Like most plants, lentils are not hybrid and it is difficult to protect IPR for lentils because they are self-pollinating (DeBeer, 2005). Self-pollinating means they will self-replicate producing identical seeds with the same hereditary makeup, making the plant easy to copy. Hybrid protection is not an option for lentils. Using IPR and hybrid protection to prevent the CRL from being copied and eroding the Canadian competitive advantage is not a feasible option.

A more sustainable competitive advantage would be obtained by Canadian lentil growers if the seeds that were exported were not viable to plant, preventing Russia and Kazakhstan from having access to the new varieties. De-hulling the lentil seeds before export provides a form of genetic protection that protects the IP of the lentils by preventing the genetics of the new lentil varieties from being copied. *Genetically protecting* the CRL varieties by de-hulling would not alter the lentils genetics, but prevents the genetics from being copied. If new CRL varieties are not available to Russia and Kazakhstan, they have to develop their own lentil varieties to be competitive. Development of new lentil varieties is a new area for Russia and Kazakhstan and will involve skills that will need to be developed. Time is required to develop perfect skills and methods, thereby slowing the rate of Russia and Kazakhstan in their competitive positioning. Canada already has the experience and the skills that are required for developing new lentil varieties, which gives them a competitive advantage over Russia and Kazakhstan (Cohen and Levinthal, 1990). De-hulling the lentils before export would provide the protection needed to prevent Russia and Kazakhstan from having access to the new varieties, giving Canadian lentil growers a sustainable competitive advantage.

2.6 Summary

Saskatchewan’s ideal lentil growing climate and their ability to develop new varieties has lead Canada to become the largest lentil producer in the world (FAOSTAT, 2012a). Lentils grow well in Saskatchewan’s climate because they are a cold season crop. The research and development at the Crop Development Centre has not only increased the supply of lentil varieties and the quality of Canadian lentils but has also improved lentil yield potential. Saskatchewan’s very effective breeding system for lentils has been obtained because of levies collected by SPG from Saskatchewan lentil producers and there well organized value chain. The breeding system has allowed Saskatchewan lentil growers to have superior genetics and a competitive advantage in the lentil industry (Gray and Scott, 2003).

Currently the competitive advantage that is gained by the development of new Canadian varieties only lasts for a short time because Russia and Kazakhstan’s ability to grow exported CRL varieties. When Russia and Kazakhstan grow CRLs, it negatively impacts Canadian lentil growers because their competitive advantage erodes, along with their higher profits. Preventing Russia and Kazakhstan from obtaining the IP of the new CRL varieties by de-hulling provides the protection that is needed to slow the erosion of the Canadian lentil industries competitive advantage.

The next chapter determines the effects of other countries adopting the new CRL varieties and the impacts to the lentil market. Chapter Three also examines a conceptual framework of the international lentil market and how the new CRL’s will impact the world lentil market as the new CRL varieties are adopted in Canada, Russia and Kazakhstan.

3. Chapter Three - Conceptual Framework

3.1 Introduction

Chapter Three examines adoption theory as well as the innovation treadmill theory. Those theories will aid in the formation and development of the conceptual model. The process of adopting an innovation over time is examined in section 3.2. The next section provides insights on how the innovation process can lead to innovation treadmill because of increases in supply, which causes decreases in price. The process of developing a conceptual model that can be used to determine the effects of a new lentil variety relies on the theory of adoption and the innovation treadmill will be explained in section 3.4. The conceptual model is a crucial component of this thesis and will aid in the establishment of the theoretical model in Chapter Four to show how the Canadian lentil industry can be affected when there is *no genetic protection (noGP)* for new CRL varieties versus when there is *GP* for new CRL varieties. Section 3.5 summarizes Chapter Three.

3.2 Adoption and Diffusion

When an innovation is invented or developed, the process that follows the innovation is diffusion and adoption or rejection. New innovations or ideas are very difficult to get adopted and require lengthy periods of time. Rogers (1962) defines diffusion as "the process through which an innovation is communicated through certain channels over time among the members of a social system." The four main elements of diffusion of an innovation are: (1) innovation, (2) communication channels, (3) time and (4) the social system (Rogers, 1962; 2002). An innovation is an object, idea or practice that is perceived as new to the individuals. Communication channels are the special way that messages are spread to individuals about an innovation. Members in the social system communicate to each other about the new innovations, allowing for adoption. There is some uncertainty in diffusion because the innovations are new to the individuals (Rogers, 1962). Diffusion of an innovation leads to the adoption process.

Adoption is the process of transferring information about the innovation to the consumer until the innovation is accepted and implemented. Before an innovation can be adopted the innovation process must take place. There are five stages in the innovation-decision process that helps an individual to adopt an innovation. The first stage is where the consumer gains knowledge about the innovation. In the second stage, the consumer will create an opinion of the value of the innovation based on the information that was gathered. A decision is then made as to whether or not to adopt the innovation in the third stage. The fourth stage is where the consumer puts their decision into action, to adopt or not to adopt. In the final stage consumers will analyze the decision they made. If they adopted the innovation, they will critique the innovation and assess whether the innovation was appropriate. The speed of the innovation-decision is dependent on the knowledge and the trust gained by consumers through the information channels (Rogers, 1962).

The adoption process behaves in a manner that forms an s-shape diffusion curve (Kinnunen, 1996). The s-shape curve represents a growth curve where the adoption ranges from zero to 100 percent. No adoption of an innovation has occurred when the curve is at zero. When the curve is at 100 percent it means that there is full adoption. The diffusion curve shows the adoption rate of an innovation during a period of time (Rogers, 1962). The rate at which it takes individuals to adopt an innovation is classified into five sections and is shown on the diffusion curve in Figure 3.1. The five classifications of adopters are: (1) innovators, (2) early adopters (3) early majority (4) late majority, and (5) the laggards. The innovators are actively seeking information about new ideas, which allows those individuals to be the first to adopt an innovation (Rogers, 1962). Innovators make up 2.5 percent of the individuals in the system to adopt an innovation. Early adopters are next, accounting for 13.5 percent of the individuals to adopt an innovation. Potential adopters will get advice and information about an innovation from the early adopters. The next section is the early majority, 34 percent of the individuals in the system to adopt an innovation can be found in this section. Like the early majority the late majority has 34 percent of the adopters. The last section is the laggards; they account for 16 percent of the individuals in the system to adopt an innovation. The laggards will only adopt when their peers have already adopted and are satisfied with the innovation (Roger, 2002).

When SPG releases a new lentil variety, it is only released to Saskatchewan lentil growers, because they are the growers who have participated in the check-off program. Growers not in Saskatchewan have to wait about one or two years until the pedigreed seed becomes available (Gray et al., 2008). Like other innovations, it takes time for all Saskatchewan growers to adopt the new variety. The process of adopting a lentil variety is the same as adopting an innovation. The innovators and early adopters in Saskatchewan are the first to adopt the new variety. This will spread to the majority of adopters and so forth. When the pedigreed seed becomes available to the Canadian market, adoption will occur in the rest of Canada. The rate of adoption will depend on how fast diffusion occurs along the communication channels.

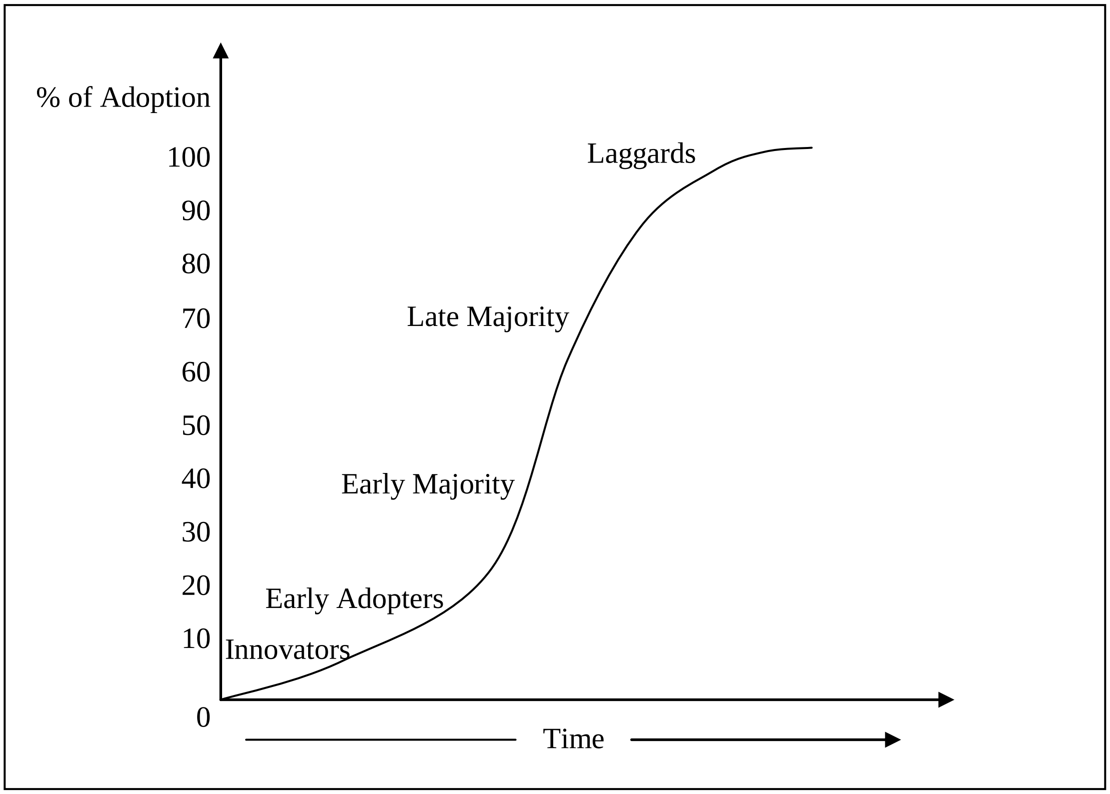

Figure 3.1 Diffusion Curve
Source: Kinnunen, 1996; Rogers, 1962

3.3 The Innovation Treadmill

The innovation treadmill concepts describes how perfectly competitive firms behave in the market and how the market reacts to changes. Economic development and innovation allows individual perfectly competitive firms to gain higher profits. Higher profits vanish when most of the firms adopt new innovations. As more and more firms adopt the new innovation, yields increase, pushing the supply curve to the right leading to a lower equilibrium price. Firms are no longer innovating to gain higher profits; they will innovate to break even (Dewar, 1988).

Schumpeter's innovation cycle and Willard Cochran's treadmill hypothesis are very similar, but they have some differences. Schumpeter's innovation cycle focuses on how the creation of new technology eliminates the old technology. Willard Cochran's treadmill hypothesis focuses on the adoption process of innovation, and how adopting new produces affect farmers in the market.

3.3.1 Schumpeter's Innovation Cycle

Joseph Schumpeter (1934) worked on the theory of economic development. Firms in the competitive market are trying to innovate to earn additional profits. Innovation is brought on by the entrepreneurs through the creation of new opportunities and ideas such as new technology (Dewar, 1988). New technologies are opportunities for entrepreneurs, because they can lead to an increase in profits (Schumpeter, 1934). The new technology will lower the per unit costs of the products which will allow the firm to receive entrepreneurial profits (Dewar, 1988). Other firms will hear or see the entrepreneurial profits made from the new technology (Schumpeter, 1934) and that encourages firms to adopt the new technology (Dewar, 1988). Creative destruction occurs as firms move towards new technology, because the old technology will become obsolete. Entrepreneurs are always trying to innovate and move towards superior methods which allow them to receive entrepreneurial profits. This causes the market to change by increasing supply, which creates a new equilibrium (Schumpeter, 1934). This is the circular flow of economic development; hence, Schumpeter's innovation cycle (Dewar, 1988).

3.3.2 Willard Cochran's Treadmill Hypothesis

Willard Cochran's (1958) theory of the production treadmill is based on farmers' need to innovate to lower costs. Farmers participate in a perfectly competitive market, producing homogeneous goods that have an almost perfectly elastic demand. Farmers have little or no market power and are forced to take prices the market offers. Prices offered to the farmer by the market are set where price is equal to average cost in the long run. Farmers are not able to influence prices, so individual farmers will try to decrease their costs of production. Farmers are always looking for new ways to decrease their costs. Decreasing costs can be done by adopting new technological advances, such as new equipment or new plant varieties. New equipment can lower the per unit cost of production by being more efficient, therefore allowing the farmer to earn higher profits. New plant varieties, developed through plant breeding, will have higher yields and have enhanced tolerance to specific herbicides. Using the new plant varieties could allow early adopters to earn higher profits because production increases, inputs used decrease, and prices stay the same. This gives farmers a powerful incentive to always be searching and adopting new technological advances (Cochran, 1958).

Early adopters of the new technologies receive increased profits, because the farmers will have a larger amount of grain for sale, while the small number of early adopters does not alter the total supply of the commodity enough to change the world price. Other farmers will start to adopt the new technology when they hear that it reduces costs. This leads to a widespread adoption of the new technology, which shifts total supply of the commodity to the right. Due to the increase in the supply of the commodity, prices fall. The increased profits that were once received for the new technology advancement by the farmers who innovated first have vanished. Cochran referred to this as the technological treadmill. The average farmers who innovated in the middle do not see the increased profit for very long (Cochran, 1958). ‘Laggard’ farmers who are slow to adopt the new technology do not see the increased profits. They are forced to adopt new technology because they will lose money as the world prices change. Farmers that do not innovate will continue to lose money and will eventually exit the industry (Dewar, 1988).

3.3.3 Pulse Research Spillovers

The pulse market is a perfectly competitive market. There are a large number of farmers and each farmer produces a relatively small amount of pulses compared to world production. The pulses produced are homogeneous, which means farmers in the pulse industry have no market power and the market will determine a price. Farmers are unable to increase the price of pulses but they are able to reduce their costs. Costs can be reduced by improving agricultural productivity in the pulse sector through three processes: (1) basic research, (2) applied research, and (3) adoption.

Basic research leads to the generation of knowledge about physical relationships within the industry. The applied research process is the knowledge that is used to create the technology that will be used in the industry. The SPG is a critical player for pulses because they contribute substantially in funding and conducting basic research and applied research and development in the pulse sector, which allows for the process of innovation. Research and development in the pulse sector has led to the creation of better methods of production and new technology (Gray and Scott, 2003). Better production method include knowledge of the production of pulses in the Canadian climate, diseases pulses are susceptible to and how to prevent them. All have significantly improved crops and increased yields. Having better production methods allows Canadian lentil producers to grow lentil crops successfully. Technology created from research and development includes new equipment and new pulse varieties (Gray and Scott, 2003). New equipment, such as land rollers, pick-up reels, lifter guards, floaters or flexible headers and air reels has helped ease the harvesting of pulses (Vandenberg and Risula, 2010). New pulse varieties have allowed farmers to produce higher yields and have plants that are resistant to various diseases. The new varieties allow farmers to reduce costs by reducing inputs such as labour and pesticides. Higher yields and new equipment increases production, leading to an increase in farm income. When yields increase, however prices adjust to the increased supply, which will cause a fall in price. Innovation will allow farmers to earn additional profits for a short while until prices adjust to the increased yields that are caused by innovation (Gray and Scott, 2003).

The farmers will have increased yields due to innovation and they will have not used additional inputs which is why profits will be increased (Gray and Scott, 2003). Producers in other countries will see or hear of the new technology, and will copy the new technology if it is suitable for their conditions. The issue is producers of other countries will gain from the new technology without paying for the initial cost of the research and development that was funded in Saskatchewan (Gray and Scott, 2003). This is an example of a research spillover, which occurs when one company funds research and development in order to increase profits or decrease costs, and other companies use the product and receive the benefits without having the costs (Gray and Malla, 2007).

3.3.4 Revenue

Revenue in this thesis is used to determine if yields are increasing at a faster rate than prices are decreasing. Revenue is determined by multiplying price with yields. By multiplying the price and the yields, it is possible to compare the change in price with the change in yields. For Figure 3.2, real 2012 prices and a yield index will be used to determine the revenue for wheat and lentils. Wheat revenue is used to compare lentil revenue because wheat is the largest crop in Canada, which will provide a good base to indicate the revenue differences in the two crops. The wheat yield index uses the variety Manitou as its base, and the lentil yield index uses the variety Laird as its base. The trend line for wheat revenue is horizontal, indicating that the wheat revenue has remained constant for the past 26 years. The constant wheat revenue means that wheat prices are decreasing at the same rate as wheat yields are increasing. Lentil revenue trends downward, which can be seen in Figure 3.2. When the trend line for revenue slopes downward, lentil prices are decreasing at a faster rate than lentil yields are increasing. When comparing wheat revenue to lentil revenue, this shows that wheat is following the treadmill hypothesis theory. For lentils, this shows that lentil production is beyond the treadmill hypothesis, indicating the rapid rate of the adoption of lentils is occurring faster than the growth in demand.

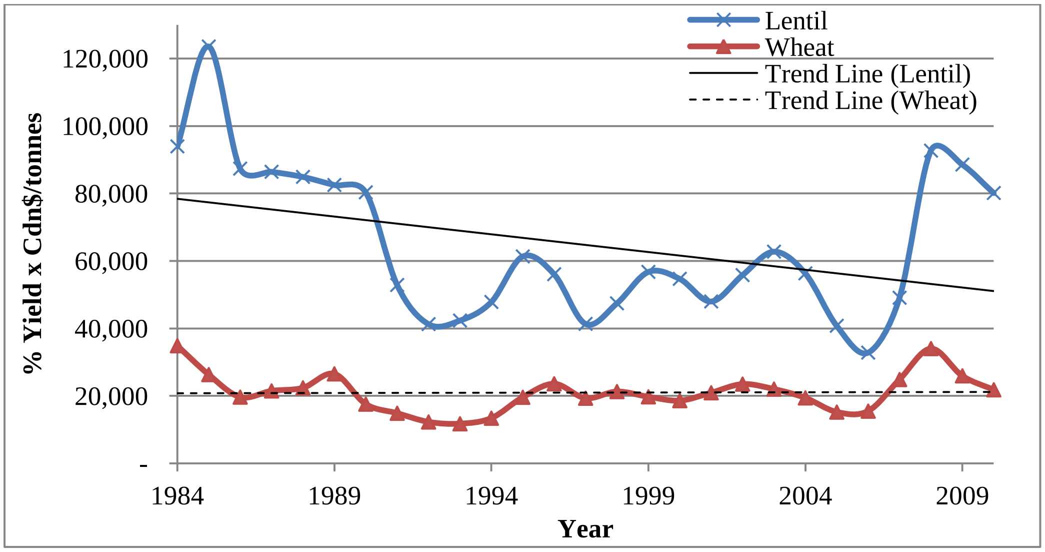

Figure 3.2 Average Canadian Lentils and Wheat Revenue, 1984-2011
Source: FAOSTAT, 2012b; FAOSTAT, 2012c; Morgan, 2012; Saskatchewan Agriculture and Food, 1990; SaskSeed Guide, 1984-2012; and Statistics Canada, 2012a

3.4 Conceptual model

The operation of the lentil market can be explained using a dynamic, multi-country, multi-period five panel partial equilibrium model. This model is provided in Figure 3.3, indicating the lentil supply for Canada, Russia, Kazakhstan, the rest of the world and the world market in the long run. Canada will be used as one of the countries in the model to determine the effects of preventing other countries from using new lentil varieties developed in Canada. Russia and Kazakhstan are singled out in the model because those two countries have the potential to use these new lentil varieties to become a large competitor to Canada in the lentil export market. In this model the rest of the world (ROW) represents every country in the world with the exceptions of Canada, Russia and Kazakhstan. ROW is used in the model to show the impact that the new CRL varieties have on other countries. The dynamic, multi-country, multi-period five panel partial equilibrium model shows how the increase in the supply of one country or many countries will affect the global supply of world lentils, and how world prices will change when supply increases. Understanding why world prices change when countries change the amount of production they supply provides insight into how producers will be affected. This model can also be used to show how the effects of protecting the IP of new CRL varieties through *GP* will affect the lentil market.

The market will act differently in the long-run compared to the short-run. It will take a few years for the new varieties of red lentils in Canada to be obtained by producers in Russia and Kazakhstan. The lag that occurs for new CRL varieties to be obtained by Russia and Kazakhstan is because it takes time for the stock of the seeds to increase and for the seeds to be spread. Therefore we will only be looking at the long run model.

3.4.1. Long-Run Functioning of the Lentil Market

In the long-run model, Canada will have a supply curve of S_{Cdn}, which can be seen on the left hand panel of Figure 3.3. The Canadian supply curve illustrates the positive relationship between the quantity of Canadian lentils supplied and its price. Kazakhstan will have a supply curve of S_{Kaz}, Russia will have a supply curve of S_{Rus} and the ROW will have a supply curve of S_{ROW}, which can be seen in the middle three panels of Figure 3.3. All of the countries supply curves illustrate the positive relationship between the quantity of lentils that country supplies and their price. World supply curve S_W is illustrated on the right hand panel of Figure 3.3. The world supple curve S_W is the total quantity of lentils that is supplied by the world. World supply is equal to Canada's supply plus Kazakhstan's supply plus Russia supply plus the ROW supply, this equation is shown in Equation 3.1.

$$S_W = S_{Cdn} + S_{Kaz} + S_{Rus} + S_{ROW} \qquad [3.1]$$

World demand D_W is determined by the total quantity of lentils that is demanded by the world market (Binger and Hoffman, 1998). The equilibrium price will occur where world supply, S_W intercepts the world demand, D_W for the world market – equal to P_W. At the set world market price of P_W Canada will produce the quantity Q_{Cdn}, Kazakhstan will produce the quantity Q_{Kaz}, Russia will produce the quantity Q_{Rus}, and ROW will produce the quantity Q_{ROW}. When world price is set at P_W the quantity consumed by the world is Q_W. World quantity, Q_W of lentils produced at price P_W is equal to the sum of the quantity of all the other countries quantity of lentils at that price, shown in Equation 3.2.

$$Q^W = Q^{Cdn} + Q^{Kaz} + Q^{Rus} + Q^{ROW} \qquad [3.2]$$

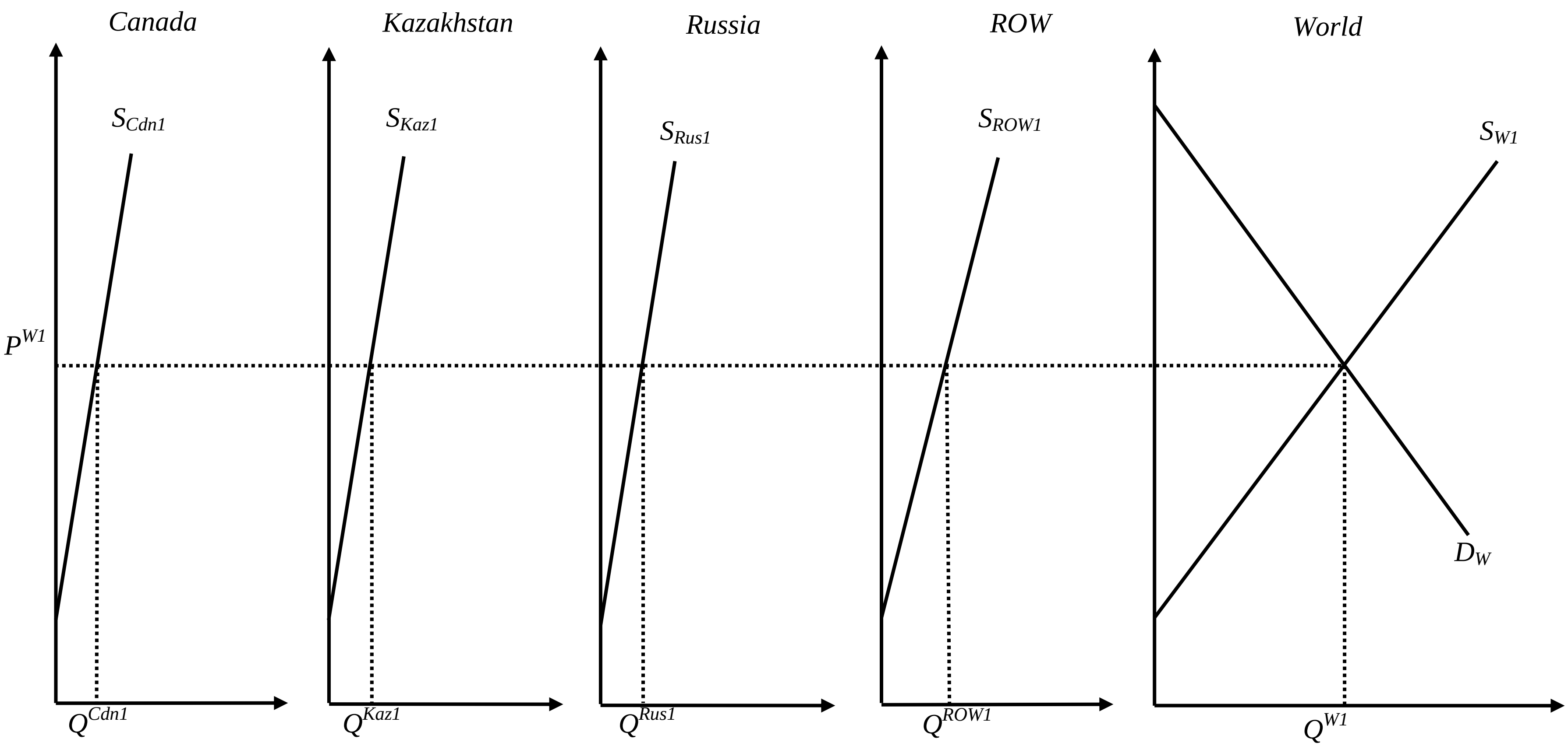

Figure 3.3 Dynamic, Multi-Country, Multi-Period Five Panel Partial Equilibrium Model Showing Long-Run Lentil Supply Before a New Higher Yielding Lentil Variety is Released into the Market

3.4.2. Long-Run Functioning of the Lentil Market When a New Higher Yielding Lentil Variety is Introduced into the Market

When a new higher yielding lentil variety is introduced into the market it will affect the quantity and price of the world supply of lentils, affecting both importing and exporting countries. As the treadmill theory suggests, when an innovation is adopted quantity increases and prices will fall, which is the case for the lentil industry when the new CRL varieties are adopted. It will take a few years for the full effect of the new variety to fully impact the market because it will take time for the new variety to be adopted. The dynamic, multi-country, multi-period, five panel partial equilibrium model can be adapted to analyze the effect of the lentil market when the new varieties are released. In the long-run, production of lentils will rise and prices will fall for all countries. In determining how the new lentil varieties will affect the dynamic, multi-country, multi-period, five panel partial equilibrium model, we will be assuming that the release of the new lentil varieties will increase the supply of lentils for each country that has access to the seed. In the model, annual growth rates for lentils that are not from new CRL varieties will be held constant.

3.4.3 A New Lentil Variety is Released in the Canadian Market

In the long-run, when a new lentil variety is released and Saskatchewan farmers have access to the seeds, those farmers will receive higher lentil yields. Not all Saskatchewan farmers will readily adopt the new variety. The innovative farmers will, and they will receive increased rents. When increased rents are received by Saskatchewan farmers, other Canadian farmers see or hear of the additional rents and will adopt the new variety. The new lentil variety will increase yields, therefore increasing the production of lentils. This will cause the Canadian supply curve to shift right from S_{Cdn1} to S_{Cdn2} for Canadian lentils; this is shown on Figure 3.4 on the left hand panel. The distance between the two supply curves S_{Cdn1} and S_{Cdn2} represents the increase in lentil yields. Kazakhstan, Russia and ROW's supply curves will not change because they do not have access to the new lentil varieties that have increased Canada's supply of lentils. The increase in Canadian lentil production will cause the world supply curve to shift right from S_{W1} to S_{W2}. The shift in world supply curve from S_{W1} to S_{W2} will be the same distance as the shift in the Canadian supply curve from S_{Cdn1} and S_{Cdn2}. The two supply curves will have the same shift because world supply is a sum of all of the other countries supply. The new world supply S_{W2} can be found

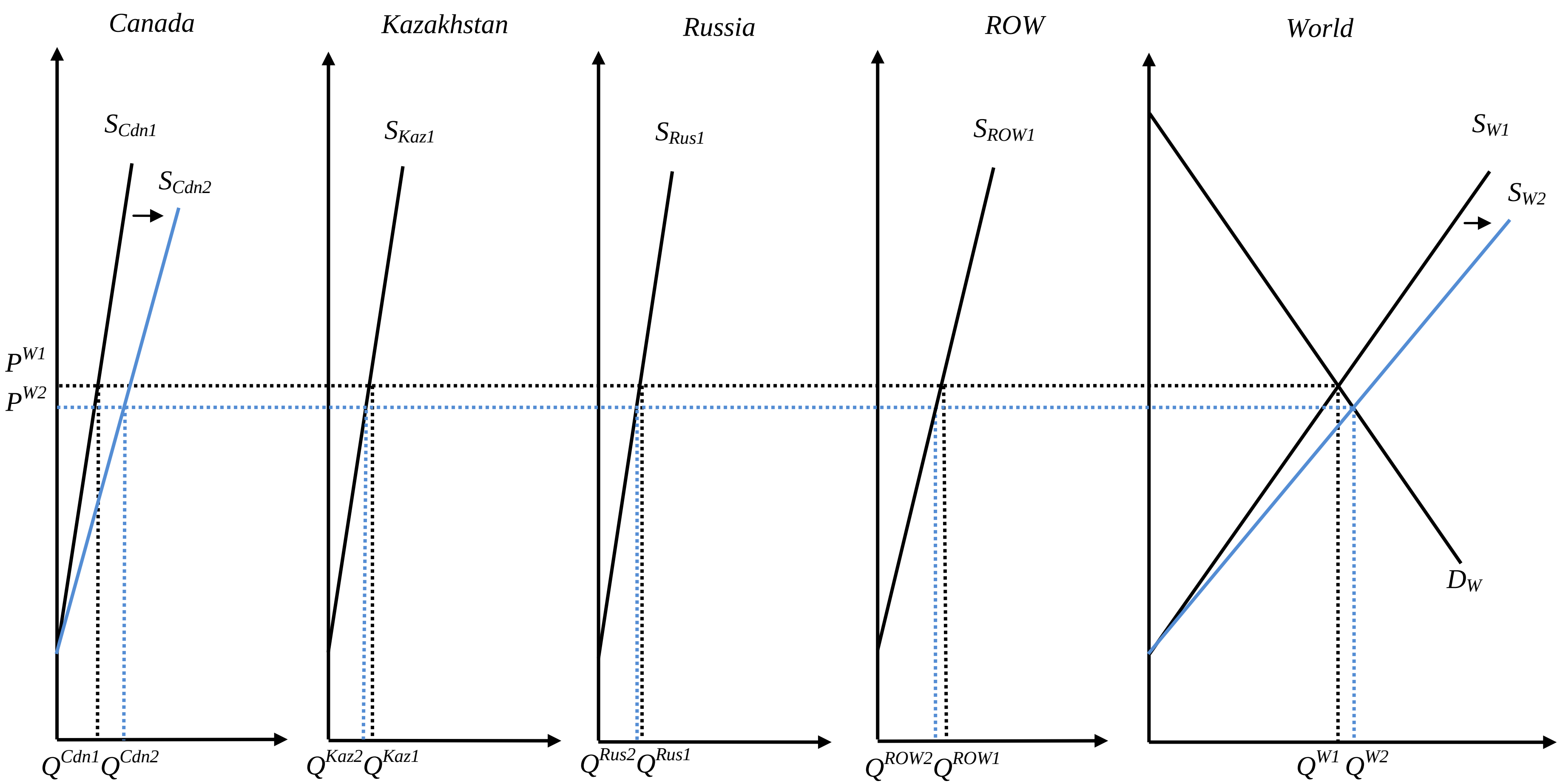

Figure 3.4 Dynamic, Multi-Country, Multi-Period Five Panel Partial Equilibrium Model Showing Long-Run Lentil Supply After a New Higher Yielding Lentil Variety is Released in the Canadian Market

using the Equation 3.1. The new world supply curve S_{W2} is equal to Canada's new supply plus Kazakhstan's supply plus Russia's supply plus ROW supply, this is shown in Figure 3.4.

The new equilibrium price will occur where the new world supply, S_{W2} intercepts the world demand, D_W for the world market – equal to P_{W2}. The world price drops from P_{W1} to P_{W2} because of the change in quantity supplied from the world lentil market of S_{W1} to S_{W2}. When the world price for lentils has decreased from P_{W1} to P_{W2}, quantity supplied by all the countries will adjust to the price change. At the set world market price of P_{W2} Canada will increase quantity produced from Q_{Cdn1} to Q_{Cdn2}. Kazakhstan and Russia will decrease the amount of quantity produced at the new world price of P_{W2}, from Q_{Kaz1} to Q_{Kaz} and from Q_{ROW1} to Q_{ROW2}. When world price is P_{W2} the quantity of lentils produced by the world will increase from Q_{W1} to Q_{W2}. World quantity, Q_{W2} of lentils consumed at price P_{W2}, this is shown in Figure 3.4. The new quantity of lentils consumed by the world can be determined by using the Equation 3.2.

3.4.4. The New Lentil Variety is Available in the World Market

In the long-run, when Canada exports the new CRL variety, other countries have access to the new seed. If the new CRL varieties are climatically suitable and have higher yields than those currently available in the other countries, such as for Kazakhstan and Russia, international producers will want to adopt the new Canadian lentil varieties. When the new lentil variety enters the world market, depending on the rate of adoption of the new variety of lentils by Kazakhstan and Russia, it will cause production of lentils to increase. This will cause the supply curve for Kazakhstan to shift to the right from S_{Kaz1} to S_{Kaz2} because of the increase in supply of lentils. The distance between the two supply curves S_{Kaz1} and S_{Kaz2} represents the increase in lentil yields for Kazakhstan. Russia's supply curve will also shift to the right from S_{Rus1} to S_{Rus2}. The distance between the two supply curves S_{Rus1} and S_{Rus2} represents the increase in lentil yields for Russia. Kazakhstan and Russia's supply curve shifts are shown in the middle two panels of Figure 3.5.

Canada's supply curve will remain at S_{Cdn2} because they have already been using the new lentil varieties and the market has already adjusted to their lentil production increase. The supply curve for ROW will not change because they will not want to use the new Canadian varieties because those countries will not be climatically suitable for the new varieties and therefore the lentils will not yield higher than their current available varieties.

The increase in Kazakhstan and Russia's lentil production will cause the world supply curve to shift right from S_{W2} to S_{W3}. The shift in world supply curve from S_{W2} to S_{W3} will be the same distance as the shift in Kazakhstan's supply curve plus the shift in Russia's supply curve. The world supply curve will shift by the same amount as Kazakhstan and Russia supply curve because world supply is a sum of all of the other countries supply. The new world supply S_{W3} can be found using the Equation 3.1. The new world supply curve S_{W3} is equal to Canada's supply, plus Kazakhstan's new supply, plus Russia's new supply, plus ROW supply, as is shown in Figure 3.5.

The new equilibrium price will occur where the new world supply, S_{W3} intercepts the world demand, D_W for the world market – equal to P_{W3}. The world price drops from P_{W2} to P_{W3} because of the change in quantity supplied from the world lentil market of S_{W2} to S_{W3}. When the world price for lentils has decreased from P_{W2} to P_{W3}, quantity supplied by all the countries will adjust to the price change. At the set world market price of P_{W3} Canadian producers will decrease quantity produced from Q_{Cdn2} to Q_{Cdn3}. Producers in Kazakhstan will increase the amount of quantity produced at the new world price of P_{W3}, from Q_{Kaz2} to Q_{Kaz3}. Producers in Russia will also increase the amount of quantity produced from Q_{Rus2} to Q_{Rus3} when world price is P_{W3}. When world price is P_{W3}, ROW will decrease the quantity of lentils produced from Q_{ROW2} to Q_{ROW3}. When world price is P_{W3}, the quantity of lentils produced by the world will increase from Q_{W2} to Q_{W3}, as shown in Figure 3.5. World quantity, Q_{W3} of lentils consumed at price P_{W3}, is equal to the sum of the quantity of all the other countries quantity of lentils at that price. The new world quantity of lentils consumed can be found using Equation 3.2.

As shown in Figure 3.5, when the rest of the world adopts the new lentil varieties, Canadian producers will lose their competitive advantage and rents will return to normal. When the rest of the world produces the new higher yielding variety of Canadian lentils world price falls from $P_{W2} – P_{W3}$ and Canadian production falls from Q_{Cdn2} to Q_{Cdn3}, causing Canadian rents to fall.

Canadian producers have a competitive advantage when they are the only country that has access to the higher yielding variety. This competitive advantage is lost when Russia and Kazakhstan adopts the new variety of lentils, because it increases lentil supply, which shifts the world supply curve of lentils to the right. When world supply for lentils increases it causes world lentil prices to fall, which negatively affect the rents of Canadian producers. As more countries

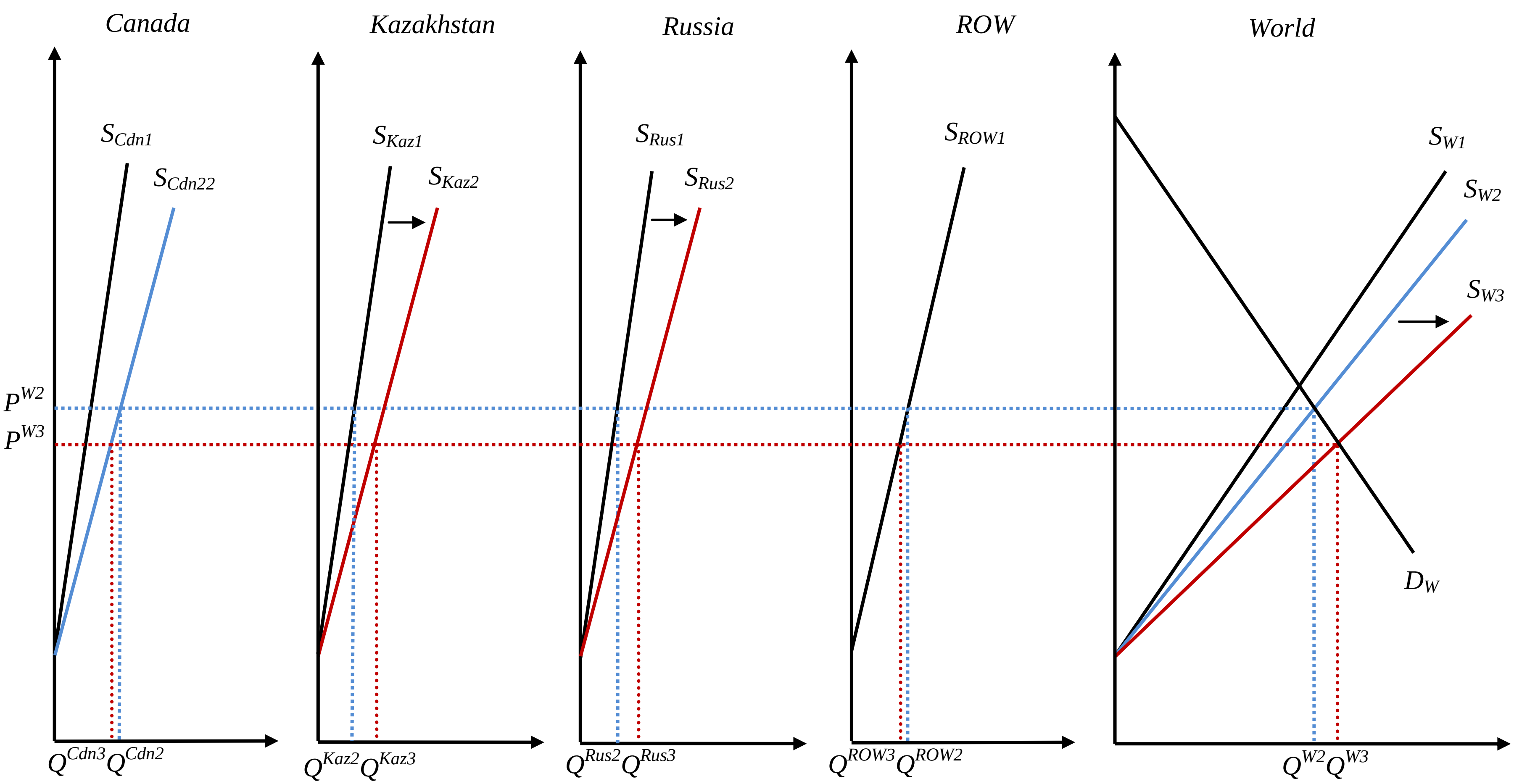

Figure 3.5 Dynamic, Multi-Country, Multi-Period Five Panel Partial Equilibrium Model Showing Long-Run Lentil Supply After a New Higher Yielding Lentil Variety is Available in the Market for Kazakhstan and Russia

adopt the new lentil varieties, downward pressure on rents for Canadian producers increases. If producers in Russia and Kazakhstan were to adopt the new CRL varieties and stay small producers of lentils, world supply of lentils would only increase by a small amount. This causes a slight decrease in world price, which means that Canadian producers will lose some rents. If many producers in Russia and Kazakhstan adopt the new CRL varieties of lentils and continue to convergence to the magnitude of the Canadian lentil market, the world supply of lentils will increase by a large amount and this will cause the world price of lentils to fall. This decrease in price will lead to large reductions in revenues for Canadian producers. Delaying the adoption of the new CRL varieties by producers in other countries will benefit Canadian producers, because it will allow them to maintain their competitive advantage for a longer period, preserving higher rents.

3.5 Summary

Adoption of an innovation can be a lengthy process that is determined by the speed and reliability of the communication channels in a social system. In Saskatchewan, it takes a few years for lentil varieties to be adopted throughout the province and even longer for the new varieties to be adopted by other countries. The treadmill theory applies to the lentil industry when new CRL varieties are adopted. The adoption of the new CRL varieties causes an increase in lentil yields, which leads to lower prices. The rate at which supply shifts and prices change are based on how fast adoption occurs for the new CRL varieties. The adoption and innovation treadmill theories are the framework behind the conceptual model. The conceptual model shows how supply and demand shifts when new varieties are adopted in the Canadian and world markets. The conceptual model shows how prices decrease when yields increase, and how widespread adoption of higher yielding Canadian varieties increases the downward movement of prices. The conceptual model is the building block for the empirical model in Chapter Four.

4. Chapter Four - Empirical Model

4.1 Introduction

Chapter Four builds on the conceptual model described in Chapter Three to develop and describe the mechanics of the empirical model used in this thesis. The structure of the empirical model is described in detail in section 4.2. The variables, including production, demand, elasticity and annual yield growth rates, are explained in section 4.3. Section 4.4 explains the dynamic framework used to measure the welfare that Canadian lentil producers will receive when they process new CRL varieties. Section 4.5 describes the limitations of the model. Section 4.6 reviews the important concepts and summarizes Chapter Four.

4.2 Model Description

The dynamic, multi-country, multi-period five panel partial equilibrium model described in this chapter is used in Chapter Five to estimate the economic impact of restricting foreign access to CRL seed. This is done by comparing two cases, a case where there is *noGP* of CRL varieties and a case where there is *GP* for CRL varieties for the years 2014 to 2034. In the case where there is *noGP* the Canadian lentil market continues to operate as it has been in the past with no restriction on the shipments of whole lentils. In the case where *GP* occurs for red lentils, the Canadian lentil producers take measures to protect the IPR of the new CRL varieties by de-hulling these lentils before export. The comparison of producer surplus for these two cases provides an estimate of the long-term impacts on Canadian lentil producers.

The model of the global lentil market consists of five linear lentil supply curves Canada, Russia, Kazakhstan, ROW, and the world supply, along with a single linear world demand curve for each year from 2014 to 2034. In each case, the intercept and slope parameters for supply and demand curves are derived from elasticity estimates, prices and quantity data reported in 2011, adjusted for future growth as described in more detail to follow.

World demand is the total quantity of lentils demanded for the world. The quantity of lentils demanded by the world is a linear function of the price and world production, and this equation is shown in Equation 4.1.

$$Q_{Dt} = a_t \cdot \frac{(1+g)^{(t-2011)}}{b_t} - P_t \cdot \frac{(1+g)^{(t-2011)}}{b_t} \qquad [4.1]$$

Where: Q_{Dt} = quantity demand at time t

t = time

a_t = the intercept at time t

b_t = the slope at time t

g = the annual growth in lentil demand

P_t = price at time t

The inverse of Equation 4.1 is:

$$P_t = a - \frac{b}{(1+g)^{(t-2011)}} \cdot Q_{Dt} \qquad [4.2]$$

For Equation 4.1, as the lentil demand increases, this will pivot the demand curve outwards to the right. As shown in Figure 4.1, in time t for the demand curve D_t, when the price is at P_1, zero quantity will be demanded and when price is at P_2, the quantity demanded will be Q_t. In time $t+1$ the demand curve D_t will pivot outwards to D_{t+1}, when the price is at P_1, zero quantity will be demanded and when price is at P_2, the quantity demanded will be Q_{t+1}. The shift in the demand curve is shown in Figure 4.1.

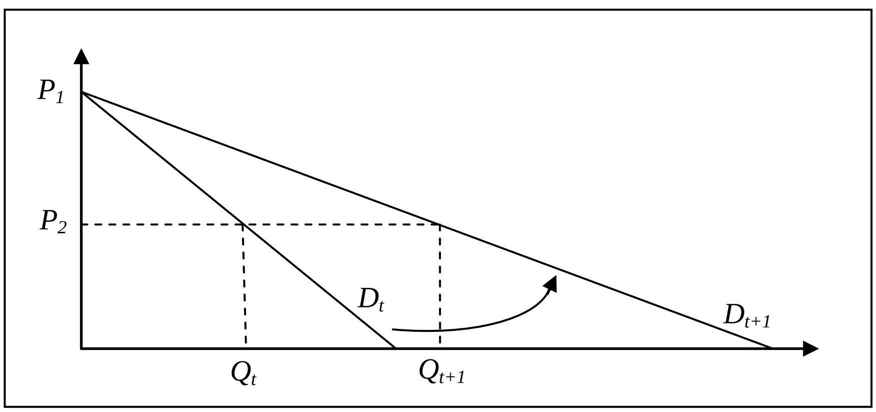

Figure 4.1 Rotation in the Demand Curve in time t to time t+1

In this thesis, world demand will be estimated to increase at the same rate by the overall demand for agricultural products, which is estimated by Climate Change, Agriculture and Food Security (CCAFS), which is a global agricultural research partnership, to increase by 1.1 percent per year till 2050. Agricultural products included in the study by CCAFS are food, feed, fibre and biofuels. Demand for agricultural products will increase because of an increase in population growth and changes that will occur in diets (CCAFS, 2012). Income elasticity for lentils is approximately zero, which means that when income increases, some consumers will move from low protein staples to pulses and other consumers will move from pulses to meats, indicating that the increase of 1.1 percent per year in world demand is a feasible measurement. The annual growth in demand for lentils will be calculated into the model using a demand growth factor for lentil; this is represented in Equation 4.3.

$$G_t = (1 + g)^{t-2011} \qquad [4.3]$$

Where: G_t = the demand growth factor for lentils at time t

g = the demand for agricultural products per year

The quantity of lentils supplied by the individual countries; Canada, Russia, Kazakhstan and ROW; will vary depending on the area of lentils seeded and the yield of the selected varieties. Equation 4.4 represents the quantity supplied of lentils.

$$Q_{St} = A_t \cdot \hat{Y}_t \qquad [4.4]$$

Where: Q_{St} = quantity supplied at time t

A_t = area at time t

$\hat{Y}_t$= yield growth factor at time t

The yield growth factors for lentils are based from the year 2011, which means that the yield growth factor in 2011 will be equal to one; this is shown in Equation 4.5.

$$\hat{Y}_{2011} = 1.00 \qquad [4.5]$$

The yield growth factor will increase in the following years and will be calculated for the years 2012 to 2034 in this model; this is represented in Equation 4.6.

$$\hat{Y}_t = \hat{Y}_{t-1} \cdot (1 + \delta_t) \qquad [4.6]$$

Where: $\hat{Y}_t$ = yield growth factor at time t

$\hat{Y}_{t-1}$= yield growth factor for year t-1

δ_t = yield growth rate in year t

Annual lentil growth factors and rates are described in greater detail in section 4.3.4. Annual lentil growth factors and rates for all the countries will also be provided in section 4.3.4 (Table 4.1).

The area of lentils that is grown for each country is important in order to determine the quantity of lentils grown. Area is a function of revenue per hectare or price times expected yield, which mean that the area of lentils seeded will be determined by the price and the yield factors of the lentil varieties relative to other crop options. This is shown in Equation 4.7.

$$A(P,\hat{Y})_t = a_t + b_t(P_t \cdot \hat{Y}_t) \qquad [4.7]$$

Where: $A(P, \hat{Y})_t$ = area as a function of prices and yields at time *t*

a_t = intercept at time *t*

b_t = slope at time *t*

P_t = price at time *t*

$\hat{Y}_t$ = yield growth factor at time *t*

Now that area is defined as a function of prices and yields, the equation for quantity supplied for lentils can be determined by taking Equation 4.7 and substituted it into Equation 4.4.

$$Q_{St} = [a_t + b_t(P_t \cdot \hat{Y}_t)] \cdot \hat{Y}_t \qquad [4.8]$$

$$Q_{St} = a_t\hat{Y}_t + b_tP_t\hat{Y}_t^2 \qquad [4.9]$$

The intercept and the slopes for the functions will vary for both the case where there is *noGP* for red lentils and the case where there is *GP* for red lentils in the model. As shown in Figure 4.2, in time *t* for the supply curve S_t, when quantity produced is at zero price will be set at P_t. At time *t+1* the supply curve S_t will pivot outwards to S_{t+1}, when the quantity supplied is at zero, the price will be set at P_{t+1},this is shown in Figure 4.2.

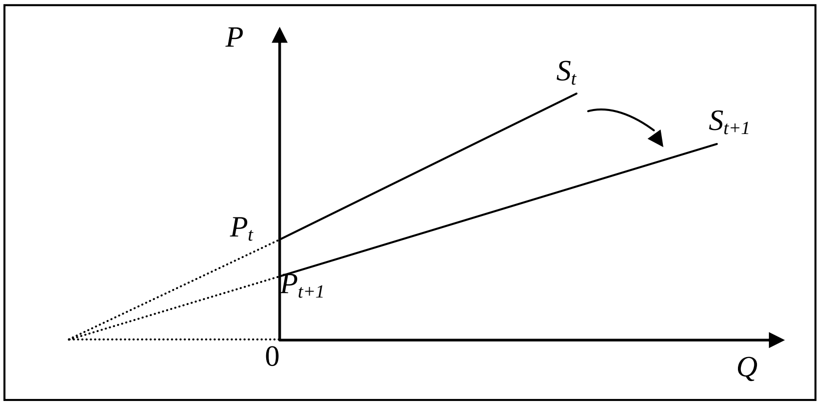

Figure 4.2 Rotation in the Supply Curve in time t to time t+1

World supply is the sum of total quantity supplied by the other lentil supply markets: Canada, Russia, Kazakhstan and ROW. World price will be determined where world supply intercepts world demand. To formulate the world price for lentils the equation used will set the world supply for lentils, which was shown as Equation 4.1, equal to the world demand for lentils, which was shown as Equation 4.9. Where Equation 4.1 equals Equation 4.9 is used to determine world price. Equation 4.12 shows how world price is determined.

$$Q_{St} = Q_{Dt} \qquad [4.10]$$

$$a_t\hat{Y}_t + \ b_t P_t \hat{Y}_t^2 = a_t \cdot \frac{(1+g)^{(t-2011)}}{b_t} - \ P_t \cdot \frac{(1+g)^{(t-2011)}}{b_t} \qquad [4.11]$$

$$P_t = \frac{[a_{Dt} \cdot \frac{(1+g)^{(t-2011)}}{b_{Dt}}] - [a_{St}\hat{Y}_t]}{[b_{St}\hat{Y}_t^2] + \frac{(1+g)^{(t-2011)}}{b_{Dt}}} \qquad [4.12]$$

Where: P_t = price at time t

t = time

a_t = the intercept at time t

b_t = the slope at time t

g = the annual growth in lentil demand

$\hat{Y}_t$ = yield growth factor at time t

D = demand

S = supply

4.3 Model Variables

There are many variables used in order to develop the theoretical model that represents the lentil supply chain. The variables used are production, demand, elasticity, and annual growth rates.

4.3.1 Production

Lentil production for Canada, Russia and ROW was taken from 2011, the most recent year available. In 2011, Canada produced 1.53 million tonnes of lentils, Russia produced 33,000 tonnes of lentils and ROW produced 2.85 million tonnes of lentils (FAOSTAT, 2012a). In 2011, Food and Agriculture Organization (FAO) has no published estimates of lentil area available for Kazakhstan (FAOSTAT, 2012a) but there are anecdotes of some observed production (Boersch, 2013). For the purpose of this model, an assumption that lentil area for Kazakhstan was 10,000 hectares in 2011 is used. This amount was chosen because it was based from the FAO data for Russia's lentil production. Russia was chosen to base Kazakhstan's initial production from because of their geographic location, their similarities in growing seasons, climate, and their transportation issues.

Four scenarios based on convergence will be used in this model in Chapter Five; the scenarios will look at different level of lentil growth in Russia and Kazakhstan from 2014 to 2034. When Kazakhstan grows lentils on 10,000 hectares, they will produce about 7,000 tonnes of lentils, equal to an average yield rate of 0.7 tonnes of lentils per hectare. This average yield rate that was attained for Kazakhstan is from Russia's average yield rate, due to a lack of data for Kazakhstan. The scenarios that are used for this thesis are examined in Chapter Five. World supply of lentils is the sum of lentil production of Canada, Russia and ROW. Under these scenarios world production of lentils will change, depending on the level of growth of Russia and Kazakhstan's lentil industries.

4.3.2 Demand

The quantity demanded for lentils by the world is the quantity produced by the world market in 2011. The assumption that world demand for 2011 is equal to world supply in 2011 is used in this model.

4.3.3 Elasticity

Elasticities used in this thesis are drawn from two published sources. For elasticity of supply, Gray et al. (2008) calculated a range of different supply elasticities for the years 1984 to 2024. Due to the fluctuation from year-to-year of the elasticity of supply for lentils in 1984 to 2024 an average of those years were taken, to get an average elasticity of supply for lentils of 3.358 (Gray et al, 2008), which is used for all of the countries in this model. While this assumption may not match reality, it was necessary because elasticity of supply will fluctuate slightly between countries and from year to year. Demand elasticity for lentil imports in the long run was calculated by Agbola and Damoense (2005) for India. India is a largest producer and is the largest consumer of lentils and is a major importer of lentils (Saskatchewan Pulse Growers, 2012b). Agbola and Damoense (2005) calculated elasticity of demand for India's lentil imports in the long-run is negative 0.87 (Agbola and Damoense, 2005). India's demand elasticity will be used for this thesis because of the magnitude of India's position in the lentil market.

4.3.4 Annual Yield Growth Rates for when there is *No Genetic Protection*

Canadian lentil varieties have had large yield increases since lentils were first grown in Canada, beginning in the 1970s. The increases in green lentil yields have been nearing their plateau in the last decade, while the yield for red lentils has continued to increase, but at a slower rate. The rate at which yields of Canadian green lentil varieties are increasing is expected to stay at half a percent per year, from 2014 to 2034. For CRL varieties, yields have been increasing at a rate of three percent per year from 2007 to 2013. The high rate of three percent per year for CRL yield increases is not expected to last in the upcoming years. Vandenberg (2013) predicts that in the next ten years, yield growth rates per year for red lentils will gradually slow down to a two percent increase per year and will maintain a two percent yield growth rate per year after the ten years (Vandenberg, 2013). The growth rates for lentil yields will be calculated into the model using a yield growth factor for lentil yield increases. The annual lentil yield growth rates and factors are shown in Table 4.1.

Russia and Kazakhstan will be using CRL varieties, therefore these yield growth rates per year for the lentils will be the same across the three countries. When new CRL varieties are released they are only available for Canadian producers. Russia and Kazakhstan have to wait one year after the new lentil variety is released in Canada, in order to obtain seed. Both Russia and

Kazakhstan will have the same yield increases per year for red lentils as Canadians but with a one year lag.

CRL varieties are not used by ROW, therefore they will have a different lentil yield rate per year than the Canadians. Vandenberg (2013) predicts that ROW yield growth increases per year will be half a percent and will stay fairly constant unless more funding is available for research and development in the lentil industry. If and when more funding is available in the lentil industry for ROW, it will take those countries a long time to see benefits from research and development. Benefits from research and development for ROW will take time because they will be starting at the beginning and there is a learning curve to overcome.

4.3.5 Annual Yield Growth Rates for When There is *Genetic Protection*

When Canadian firms protect the IP for their red lentils through *GP*, Canadian firms will de-hull new lentil varieties. De-hulling of the new red lentil varieties will take place for four years once the new variety is released to lentil producers in Canada. By de-hulling the new varieties, it will protect the new CRL varieties IPR, giving Canadian lentil producers a competitive advantage in the lentil industry. A competitive advantage is received for four years by Canadian lentil producers, because they are able to prevent other countries from using their new varieties through *GP* for those four years. An assumption of four years was chosen to use for an analysis after consulting with experts in the pulse industry. Over time leakages occur in the duration of when *GP* process is achieved. Based on a 20:1 seed to production ratio it would take several years to produce enough seed to permit widespread adoption of the new CRL varieties if there were leakages. A sensitivity analysis of this assumption is performed in section 5.8 of Chapter Five. After four years of protecting the same lentil variety, it will no longer be the highest yielding variety available in the Canadian market because new improved varieties are being released every year.

De-hulling new lentil varieties will not affect the yield growth factor for lentils in Canada. The yield growth factor will be calculated the same way as in the case where there is *noGP* for red lentils for Canadians. However the yield growth factor for lentils in Russia and Kazakhstan will change in the case where *GP* takes place for red lentils. When Canadian firms de-hull new lentil varieties, this prevents Russia and Kazakhstan from having access to superior lentil genetics. When *GP* takes place for red lentils Canadians will start de-hulling each new lentil varieties for a four year period, i.e. a 2014 lentil variety will be de-hulled until 2018. In

2018 the 2014 lentil variety will be exported as a whole lentil around the world, which is when Russia and Kazakhstan will have full access to the 2014 lentil variety. From 2014 to 2018 Russia and Kazakhstan will not have access to the new Canadian lentil varieties and therefore their yield growth rate per year for lentils will fall to half a percent. In 2018 when the 2014 CRL variety becomes available, Russia and Kazakhstan will use the new variety which will give them higher yields. When Russia and Kazakhstan use the CRL varieties, their yield rates per year for lentils will again follow the Canadian yield growth rates per year, but with a four year lag. This four year lag allows Canadian lentil producers to maintain a competitive advantage in the lentil industry over Russia and Kazakhstan. The annual yield growth rates per year can be seen in Table 4.1 for all countries for both cases; the *noGP* of Canadian lentils case and the *GP* of Canadian lentils case.

The yield growth rate for ROW will not be affected when the Canadian firms use *GP* for their new lentil varieties; ROW will continue to have a yield growth rate per year of half a percent. When *GP* occurs for CRL varieties it will not affect the growth rate of lentils demanded by the world market. Demand for lentils will continue to increase by 1.1 percent per year, which is the overall demand for agricultural products.

Table 4.1 Canada, Russia, Kazakhstan, and ROW's Annual Lentil Growth Factors/Rates and the Demand Growth Factor for Lentils for No Genetic Protection and Genetic Protection, 2011-2034

Country	Canada				Kazakhstan & Russia				ROW		World	
Case	*NoGP* and *GP*		*NoGP* and *GP*		*NoGP*	*GP*	*NoGP*	*GP*	*NoGP* and *GP*		*NoGP* and *GP*	
Lentil Colour	Green	Red	Green	Red	Green/Red	Green/Red	Green/Red	Green/Red	Green/Red		Green/Red	
Yield Rate/Growth	$\hat{Y}_t$	$\hat{Y}_t$	δ_t	δ_t	$\hat{Y}_t$	$\hat{Y}_t$	δ_t	δ_t	$\hat{Y}_t$	δ_t	$\hat{Y}_t$	δ_t
2011	1.000	1.000	0.50%	3.00%	1.000	1.000	3.00%	3.00%	1.000	0.50%	1.000	1.10%
2012	1.005	1.030	0.50%	3.00%	1.030	1.030	3.00%	3.00%	1.005	0.50%	1.011	1.10%
2013	1.010	1.062	0.50%	3.00%	1.062	1.062	3.00%	0.50%	1.010	0.50%	1.022	1.10%
2014	1.015	1.093	0.50%	2.90%	1.094	1.067	3.00%	0.50%	1.015	0.50%	1.033	1.10%
2015	1.020	1.123	0.50%	2.80%	1.126	1.073	2.90%	0.50%	1.020	0.50%	1.045	1.10%
2016	1.025	1.154	0.50%	2.70%	1.157	1.078	2.80%	0.50%	1.025	0.50%	1.056	1.10%
2017	1.030	1.184	0.50%	2.60%	1.188	1.083	2.70%	0.50%	1.030	0.50%	1.068	1.10%
2018	1.036	1.213	0.50%	2.50%	1.219	1.116	2.60%	3.00%	1.036	0.50%	1.080	1.10%
2019	1.041	1.242	0.50%	2.40%	1.250	1.148	2.50%	2.90%	1.041	0.50%	1.091	1.10%
2020	1.046	1.271	0.50%	2.30%	1.280	1.180	2.40%	2.80%	1.046	0.50%	1.103	1.10%
2021	1.051	1.299	0.50%	2.20%	1.309	1.212	2.30%	2.70%	1.051	0.50%	1.116	1.10%
2022	1.056	1.325	0.50%	2.00%	1.338	1.244	2.20%	2.60%	1.056	0.50%	1.128	1.10%
2023	1.062	1.351	0.50%	2.00%	1.365	1.275	2.00%	2.50%	1.062	0.50%	1.140	1.10%
2024	1.067	1.378	0.50%	2.00%	1.392	1.305	2.00%	2.40%	1.067	0.50%	1.153	1.10%
2025	1.072	1.406	0.50%	2.00%	1.420	1.335	2.00%	2.30%	1.072	0.50%	1.166	1.10%
2026	1.078	1.434	0.50%	2.00%	1.448	1.365	2.00%	2.20%	1.078	0.50%	1.178	1.10%
2027	1.083	1.463	0.50%	2.00%	1.477	1.392	2.00%	2.00%	1.083	0.50%	1.191	1.10%
2028	1.088	1.492	0.50%	2.00%	1.507	1.420	2.00%	2.00%	1.088	0.50%	1.204	1.10%
2029	1.094	1.522	0.50%	2.00%	1.537	1.448	2.00%	2.00%	1.094	0.50%	1.218	1.10%
2030	1.099	1.552	0.50%	2.00%	1.568	1.477	2.00%	2.00%	1.099	0.50%	1.231	1.10%
2031	1.105	1.583	0.50%	2.00%	1.599	1.507	2.00%	2.00%	1.105	0.50%	1.245	1.10%
2032	1.110	1.615	0.50%	2.00%	1.631	1.537	2.00%	2.00%	1.110	0.50%	1.258	1.10%
2033	1.116	1.647	0.50%	2.00%	1.663	1.568	2.00%	2.00%	1.116	0.50%	1.272	1.10%
2034	1.122	1.680	0.50%	2.00%	1.697	1.599	2.00%	2.00%	1.122	0.50%	1.286	1.10%

*Note: $\hat{Y}_t$ is the yield growth factor at time t; δ_t is the yield growth rate in year t

Source: Author's calculation

4.4 Dynamic Framework for Measuring the Economic Gains from Innovation

Producer surplus (PS) is used to measure the amount of surplus that is received by lentil producers for all the countries in each scenario for this model. Producer Surplus will be measured using the PS equation:

$$PS_t = ½\,[(P^W{}_t - a) \cdot Q_t] \qquad [4.13]$$

Where: PS_t = producer surplus in year t

$P^W{}_t$ = world price at time t

a = where the supply curve intercepts the vertical axis

Q_t = quantity consumed at time t

The PS calculated in this model has been calculated as future values for each individual year. The discounted price equation will be used to change PS into present value terms; the discounted price equation is shown in Equation 4.14.

$$Discounted\ Price_t = \sum_t^n \frac{PS_t}{(1+r)^t} \qquad [4.14]$$

Where: $Discounted\ Price_t$ = Discounted price at time t

PS_t = producers surplus at time t

r = the real discount rate

n = number of years

The annual discounted price for PS will be used to measure the impact of Canadian firms protecting the IP of new CRL varieties. In each scenario, annual discounted price for PS will be taken for both cases where there is *noGP* and when there is *GP* for red lentils. The overall impact in the change of annual discounted price for PS when there is *noGP* for red lentils versus when *GP* for red lentils occurs will be calculated by comparing the results from both cases. The difference in the annual discounted price for the PS in the two cases will indicate the welfare impacts that will occur when Canadian firms process new CRL varieties to protect IP. Greater detail on the years 2014, 2024 and 2034 will show how the market is affected at various points throughout the twenty years. The discounted PS will be taken for the individual years to show the welfare impacts from year to year. The total discounted PS will be taken from 2014 to 2034, to show the net welfare impacts of processing new CRL varieties in the long-term.

4.5 Overall Expected Economic Impacts

When Canadian firms protect their IPR of their new lentil varieties through *GP*, there are many different possible outcomes of economic welfare impacts. The possible welfare impacts to the lentil industry depend on future outcomes. As the future is uncertain, several possible outcomes have been developed. From these possibilities a point estimate will be calculated. The weighted average is calculated using the percentage that a scenario will happen, multiplied by the discounted price from that scenario for the time period of 2014 to 2034, an equation shown in Equation 4.15.

$$Weighted\ Average = \varphi^{a} \cdot\ Discounted\ Price_{t}^{a} \qquad [4.15]$$

Where: $Discounted\ Price_{t}^{a}$= Discounted price of scenario *a* in the time period of 2014 to 2034

φ^{a} = the probability of scenario *a* occurring

a = scenario a, *a Ɛ(1,…4)*

t = the time period 2014 to 2034

The total weighted average is the sum of the weighted average of a set of scenarios; this is shown in Equation 4.16.

$$Total\ Weighted\ Average = \sum_{t}^{n}(\varphi^{a} \cdot Dicscounted\ Price_{t}^{a}), \text{ for } \forall\ a \qquad [4.16]$$

Where: $Discounted\ Price_{t}^{a}$= Discounted price of scenario *a* in the time period *t*

φ^{a} = the probability of scenario *a* occurring

a = scenarios 1, 2, 3 and 4

n = number of years

t = the time period 2014 to 2034

The weighted average will be taken for Canada, Russia, Kazakhstan, ROW and the global lentil industry for the time period of 2014 to 2034 to show the welfare impacts that occur when Canadian firm's use *GP* for new CRL varieties to protect IP.

4.6 Model Limitations

The dynamic, multi-country, multi-period five panel partial equilibrium model used in this thesis has some limitations. The first limitation of the model is that an assumption is made that all lentils produced in a given year are available in the market for the given year that they are produced as the model does not take into account the some lentil seeds are stored from year to year, depending on the price of lentils. This will affect the world supply and therefore the world price of lentils.

A constraint of the data is that production for lentil colour was not available for all countries except Canada. This affects the rate at which production will increase within a specific country. As for Canada, the yield rate of red lentils has been increasing at a faster rate than green lentils. This change in yield rates is established in the model. For the other countries, the yield rate for the two different lentil colours is not established in the model and production will be increasing by the yield growth rate of the red coloured lentil for Russia, Kazakhstan and ROW.

4.7 Summary

Chapter Four explains the mechanics of the empirical model that explains the background of the dynamic, multi-country, multi-period five panel partial equilibrium model. This chapter also describes the differences in the case where there is *noGP* for new CRL varieties and the case where there is *GP* for new CRL varieties. The case where there is *noGP* depicts the lentil model in 2014 to 2034 as if the Canadian lentil market continues to operate as it is with no restriction on the shipments of whole lentils. The case where *GP* occurs will depict how the lentil market will look from 2014 to 2034 if the Canadian lentil industry protects the IP by using *GP* such as de-hulling new CRL varieties. Calculating both of the cases in this model allows for them to be compared, which will show the impacts and benefits that Canadian lentil producers will receive when they *genetically protect* CRL varieties to protect IPR. The variables used in this model were chosen to allow for realistic and accurate model. The theoretical model is a crucial component of this thesis and will aid in the measurement of the effects of the economic impacts to consumers and producer benefits that will be presented in Chapter Five.

Chapter 5 - The Economic Impacts of *Genetic Protection*

5.1 Introduction

Chapter Five describes the economic impacts of *GP*, which are estimated by applying the empirical model outlined in Chapter Four to a number of scenarios. Section 5.2 describes four different scenarios for future lentil growth in Kazakhstan and Russia that are run in the model, and used as the basis of the analysis. Section 5.3 employs these four scenarios to simulate lentil production, and market outcomes when there is *noGP* and when there is *GP* for lentils. Section 5.4 shows the impacts that *GP* of lentil varieties will have on world lentil prices, Canadian lentil production, and Canadian welfare for all four scenarios. In section 5.5, a comparison of *noGP* to *GP* is used to calculate the welfare impacts for Russia, Kazakhstan, ROW, and the world lentil industries when Canadian firms use *GP* to protect their CRL varieties. Section 5.6 determines the breakeven processing margin when there is *GP* for new CRL varieties. Section 5.7 looks at the overall expected economic impact of *genetically protecting* new Canadian lentils. A sensitivity analysis is taken in section 5.8 to ensure that all the possible future outcomes are considered in this thesis. The results from Chapter Five are summarized in section 5.9.

5.2 Four Future Convergence Scenarios For Russia and Kazakhstan For the Next 20 Years

For this thesis, four different supply scenarios for future lentil production for Russia and Kazakhstan are evaluated and used collectively to estimate the economic impacts of *GP* through de-hulling lentils prior to export. As mentioned in Chapter Four, *GP* for this thesis refers to a process where the lentils are de-hulled in order to protect the genetics, and in no way are the genetics of the lentils altered. Each scenario, used to collectively span the range of plausible paths for lentil production in Russia and Kazakhstan for the years 2014 to 2034, incorporates a different rate of convergence towards Canadian lentil production. Convergence refers to the narrowing of a percentage gap in production for a leading country and developing countries (Baumol et al., 1994). For this thesis, Russia and Kazakhstan are the developing countries and they will be converging towards the Canadian lentil industry. For each convergence scenario, the economic model incorporates the production and global price effects to trace out the market equilibrium for the years of 2014 to 2034. By comparing the outcomes when there is *noGP* for lentils and to the outcome when there is *GP* of lentils, the impacts of protection are estimated for each scenario. As a final step, probability weights for each scenario obtained from a small survey of experts, is used to calculate the overall expected economic impacts of the proposed lentil de-hulling system.

In 2011, red lentil seeded area in Canada was five percent of the spring wheat area (FAOSTAT, 2012a). At prevailing 2011 prices and yields many Canadian farmers find red lentils a profitable crop and have included it in their crop rotations. Although Russia and Kazakhstan have a large spring wheat area that is also agronomically well suited to CRL varieties, both countries have very small, largely under-developed lentil industries. As the agronomic knowledge, machinery technology, and infrastructure required for lentil production becomes available in these countries, one would expect producers to recognise lentils as a valuable crop and converge toward the Canadian lentil industry's position in these markets. The rate that producers in these countries will converge will depend on a number of factors including prices, varieties, the development of farm agronomic expertise, improved grain handling and storage, improved grain transportation system, and an effective marketing system. Given this range of contributing factors, there is wide range of plausible convergence rates.

The scenarios used in this thesis are based on the concept of convergence. For the purpose of this thesis, convergence is defined as the ratio of lentil hectares to spring wheat hectares that exists in a country at 2011 prices and genetics, as a proportion of five percent ratio that existed in Canada in 2011. A assumption was made that by 2034 Russia and Kazakhstan will converge to the 2011 Canadian lentil industry. The rate of convergences for Russia and Kazakhstan does not mean that they will produce the same amount of production as the Canadian lentil industry in 2011, it means that Russia and Kazakhstan will have the same ratio of lentil hectares to spring wheat hectares as the Canadian lentil industry did as of 2011. It is assumed that Russia and Kazakhstan will not converge to the 2034 Canadian lentil production because the Canadian lentil industry will continue to grow from 2011 to 2034. The Canadian lentil industry will not be growing at as fast of a rate as Russia and Kazakhstan which means that the gap in production between these countries will be reduced. Russia and Kazakhstan will grow at a faster rate than the Canadian lentil industry because they are just starting to develop their lentil industries, and the technology and information Russia and Kazakhstan need is readily available in the market.

The four scenarios that are used for the analysis are based on the extent of convergence by 2034. The different rates of convergence towards the Canadian lentil/wheat ratio that is represented by the four scenarios will range from *full convergence* to *no convergence*. For the *full convergence* scenario, Russia and Kazakhstan's lentil industry will fully converge to the five percent 2011 Canadian lentil hectares to spring wheat hectares ratio by 2034, in a linear fashion. The model implies that in 2034, if 2011 prices and yields prevailed, Russia and Kazakhstan will be growing lentils on about five percent of the hectares used for growing spring wheat. This could be considered a best case scenario for Russia and Kazakhstan. In the second scenario, called *half convergence,* Russia and Kazakhstan will grow lentils on about 2.5 percent of the hectares that are used for growing spring wheat by 2034. In the third scenario, called *quarter convergence*, both Russia and Kazakhstan will grow their lentil industry a quarter of the way to the Canadian five percent lentil hectares to spring wheat hectares ratio by 2034. In the fourth scenario, *no convergence*, Russia and Kazakhstan will maintain the amount of hectares they are using to grow lentils and will not converge toward the Canadian lentil hectare to spring wheat hectare ratio. The *no convergence* scenario could be considered as the worst case scenario because it would mean that Russia and Kazakhstan were not able to develop their lentil industry. The n*o convergence* scenario could plausibly happen if a major economic or political disruption halts further development of the pulse industry.

Convergences for all the scenarios will be based from the 2011 data for the hectares of wheat grown in Russia and Kazakhstan. In 2011, Russia harvested about 8.3 million hectares of spring wheat and Kazakhstan harvested about 12.3 million hectares of spring wheat (FAOSTAT, 2012a). The spring wheat hectares and lentils hectares are shown in Table 5.1. In 2011, Russia harvested about 48,000 hectares of lentils. In 2011, there are no published estimates of lentil area available for Kazakhstan but there are anecdotes of some observed production (Boersch, 2013). For the purpose of developing convergence scenario, I assume that lentil area was 10,000 hectares. As described in Chapter Four (section 4.3.1), 10,000 hectares was chosen for Kazakhstan's 2011 production because it was based from Russia's initial starting point of lentil production.

Table 5.1 Spring Wheat Hectares and Lentil Hectares for Russia and Kazakhstan

Crop	Year	Country	*Full Convergence*	*Half Convergence*	*Quarter Convergence*	*No Convergence*
Percent of Convergence			5%	2.5%	1.25%	0%
Area Harvested			**000'000' Ha**	**000'000' Ha**	**000'000' Ha**	**000'000' Ha**
Spring Wheat	**2011**	**Russia**	8.28	8.28	8.28	8.28
		Kazakhstan	12.32	12.32	12.32	12.32
Area Harvested			**000' Ha**	**000' Ha**	**000' Ha**	**000' Ha**
Lentils	**2011**	**Russia**	47.58	47.58	47.58	47.58
		Kazakhstan	10.04	10.04	10.04	10.04
Lentils	**2034**	**Russia**	394.22	201.91	102.24	47.58
		Kazakhstan	586.90	300.60	152.21	10.04

Source: Author's calculation

For the scenarios of *full convergence*, *half convergence*, *quarter convergence* and *no convergence,* lentil production for Russia and Kazakhstan will start at the production level from 2011 and linearly increase to the level of convergence of the scenario by 2034. In 2011, Russia harvested about 48,000 hectares of lentils and it was estimated that Kazakhstan harvested 10,000 hectares of lentils. In the scenario of *full convergence* if both countries were to reduce spring wheat hectares to grow lentils on five percent of the spring wheat hectares by 2034, Russia would have about 394,000 hectares of lentils and Kazakhstan would have about 587,000 hectares sown to lentils, as shown in Figure 5.1 and Figure 5.2. For the scenario of *half convergence*, if both countries were able to plant lentils on 2.5 percent of the spring wheat hectares, Russia would have about 202,000 hectares and Kazakhstan would have about 301,000 hectares that would be seeded to lentils by 2034. In the *quarter convergence* scenario, when both countries converge a quarter of the way to the Canadian lentil industry, 102,000 hectares for Russia and 152,000 hectares for Kazakhstan will be used to grow lentils by 2034. In the scenario of *no convergence,* Kazakhstan and Russia will not converge to the Canadian lentil production. In 2011, Russia grew about 48,000 hectares of lentils. In the *no convergence* scenario, the amount of hectares lentils are grown on does not change and Russia will continue to grow lentils on 48,000 hectares in 2034. When *no convergence* to the Canadian lentil industry takes place for Kazakhstan, they will grow about 10,000 hectares of lentils from 2011 to 2034.

Figure 5.1 shows the hectares of lentils grown for Russia in all four of the scenarios mentioned above for the years of 2011 to 2034. In each case the parameters of the supply curve calibrated via a calculation, such that at 2011 genetic yields and prices, the area shown will follow the linear growth of each convergence path. Figure 5.2 shows the hectares of lentils grown for Kazakhstan in all four of the scenario mention above for the years of 2011 to 2034. Refer to Table 5.2 for full data on all four scenarios for lentil hectares grown in Kazakhstan and Russia for each year from 2011 to 2034.

These scenarios look at four possible outcomes that Russia and Kazakhstan could potentially expand their lentil industries in 2014 to 2034, and those scenarios are only looking at the increase in hectares used for lentil production for Russia and Kazakhstan. The next section will look at the lentil production of Russia and Kazakhstan with the yield increases they will have when using CRL varieties.

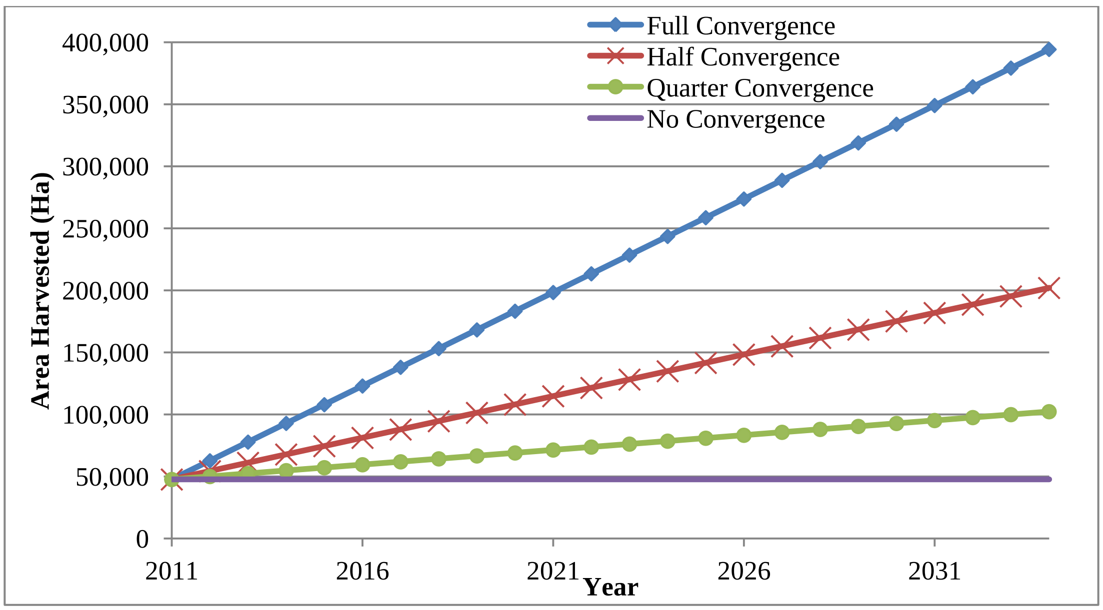

Figure 5.1 Four Scenarios of Lentil Hectares Harvested in Russia, 2011-2034
Source: Author’s calculation

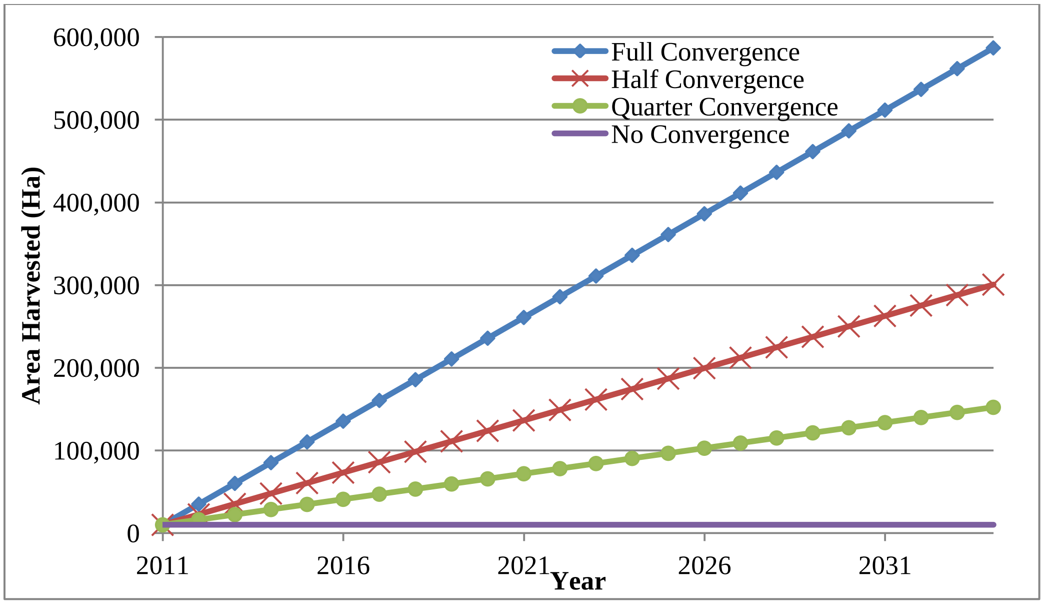

Figure 5.2 Four Scenarios for Lentil Hectares Harvested in Kazakhstan, 2011-2034
Source: Author's calculation

Table 5.2 Scenario's for Lentil Hectares in Kazakhstan and Russia, 2011-2034[3]

	Full Convergence		*Half Convergence*		*Quarter Convergence*		*No Convergence*	
Tonnes	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**
Year	**Russia**	**Kaz.**	**Russia**	**Kaz.**	**Russia**	**Kaz.**	**Russia**	**Kaz.**
2011	47.58	10.04	47.58	10.04	47.58	10.04	47.58	10.04
2012	62.65	35.12	54.29	22.67	49.95	16.22	47.58	10.04
2013	77.72	60.20	61.00	35.31	52.33	22.40	47.58	10.04
2014	92.79	85.28	67.71	47.94	54.71	28.59	47.58	10.04
2015	107.86	110.36	74.42	60.57	57.08	34.77	47.58	10.04
2016	122.94	135.45	81.13	73.21	59.46	40.95	47.58	10.04
2017	138.01	160.53	87.84	85.84	61.84	47.13	47.58	10.04
2018	153.08	185.61	94.55	98.47	64.21	53.31	47.58	10.04
2019	168.15	210.69	101.26	111.10	66.59	59.49	47.58	10.04
2020	183.22	235.77	107.97	123.74	68.97	65.67	47.58	10.04
2021	198.29	260.85	114.68	136.37	71.34	71.85	47.58	10.04
2022	213.36	285.93	121.39	149.00	73.72	78.03	47.58	10.04
2023	228.44	311.01	128.10	161.64	76.10	84.22	47.58	10.04
2024	243.51	336.09	134.81	174.27	78.47	90.40	47.58	10.04
2025	258.58	361.17	141.52	186.90	80.85	96.58	47.58	10.04
2026	273.65	386.25	148.23	199.53	83.23	102.76	47.58	10.04
2027	288.72	411.33	154.94	212.17	85.60	108.94	47.58	10.04
2028	303.79	436.41	161.65	224.80	87.98	115.12	47.58	10.04
2029	318.86	461.49	168.36	237.43	90.36	121.30	47.58	10.04
2030	333.94	486.57	175.07	250.07	92.73	127.48	47.58	10.04
2031	349.01	511.66	181.78	262.70	95.11	133.67	47.58	10.04
2032	364.08	536.74	188.49	275.33	97.49	139.85	47.58	10.04
2033	379.15	561.82	195.20	287.96	99.86	146.03	47.58	10.04
2034	394.22	586.90	201.91	300.60	102.24	152.21	47.58	10.04

Source: Author's calculation

[4] The lentil area is based on 2011 prices and 2011 Canadian genetic variety yields. The simulated area and production, in each scenario will changes depending on genetic yields and equilibrium price levels.

5.3 Production for Russia and Kazakhstan in the *No Genetic Protection* Case and the *Genetic Protection* Case

This section investigates the production levels for Russia and Kazakhstan in the case of *noGP* and with *GP* for 2014 to 2034. With *noGP*, Russia and Kazakhstan both reflect annual yield growth rates of the new CRL varieties. With *GP* genetic yield increases are lagged for four years. In all four scenarios, Russia will start producing lentils on 48,000 hectares and Kazakhstan will use about 10,000 hectares. The average yield rate that Russia produces is 0.7 tonnes of lentils per hectare. Due to a lack of data for Kazakhstan, Russia's average yield rate will be used for Kazakhstan because of their geographic location, their similarities in growing seasons, and climate. The lentil yield of 0.7 tonnes of lentils per hectare will increase as Russia and Kazakhstan use the new CRL varieties. By 2034 Russia and Kazakhstan's production will have increased, and the increase in production will vary depending on if there is *GP* or *noGP* for the lentils.

5.3.1 Full Convergence

In the scenario of *full convergence,* Russia produces 1.53 million tonnes of lentils in 2034 when there is *noGP* for CRL varieties. When CRL varieties are protected through *GP,* in the *full convergence* scenario, Russia will produce 1.33 million tonnes of lentils. When *full convergences* occurs when there is *noGP* for CRL varieties, Kazakhstan will produce 2.28 million tonnes of lentils by 2034. When there is *GP* for CRL varieties, Kazakhstan's production falls to 1.99 million tonnes of lentils. The difference in production for Russia and Kazakhstan from the case where there is *noGP* for lentils to the case where there is *GP* for lentils for all four scenarios is shown in Figures 5.3 and Figure 5.4. Table 5.3 shows lentil production for the *full convergence* scenario for Russia and Kazakhstan in 2011 to 2034.

5.3.2 Half Convergence

In the *half convergence* scenario, when there is *noGP* for lentils Russia will produce 783,000 tonnes of lentils and Kazakhstan will produce 1.17 million tonnes of lentils in 2034. When *GP* is in place for CRL varieties in the *half convergence* scenario, both countries will have a reduction in production, Russia produces 683,000 tonnes of lentils and Kazakhstan produces 1.02 million tonnes of lentils. Production for both countries is reduced when they no longer have access to new CRL varieties due to *GP*. Data for *half convergence* scenario is located in Appendix C, in Table C1.

5.3.3 Quarter Convergence

In the *quarter convergence* scenario, by 2034, when there is *noGP* for CRL varieties, Russia will produce 397,000 tonnes of lentils. When *GP* occurs, production will fall to 346,000 tonnes of lentils. By 2034 for the *quarter convergence* scenario Kazakhstan will produce 591,000 tonnes when there is *noGP* in place and 515,000 tonnes when there is *GP* for lentils. Data for *quarter convergence* scenario is located in Appendix C, in Table C2.

5.3.4 No convergence

In the *no convergence* scenario, when Russia and Kazakhstan do not converge to the Canadian lentil industry, their lentil yields will increase because they will be using Canadian lentil varieties, which increases lentil production. When there is *noGP*, Russia will produce 185,000 tonnes of lentils on 48,000 hectares, but when there is *GP*, Russia will produce 161,000 tonnes of lentils on 48,000 hectares. For the *no convergence* scenario, by 2034 when there is *noGP*, Kazakhstan will produce 39,000 tonnes of lentils on 10,000 hectares but when there is *GP*, Kazakhstan produces 34,000 tonnes of lentils on 10,000 hectares. Table 5.4 shows lentil production for the *no convergence* scenario for Russia and Kazakhstan in 2011 to 2034.

Figure 5.3 and Figure 5.4 shows when *GP* for CRL varieties is executed, production in Russia and Kazakhstan will be decreased in all four scenarios, because they will no longer have access to the new CRL varieties. Larger impacts on Russia and Kazakhstan's lentil production will occur when they have converged fully, because they have a larger lentil industry.

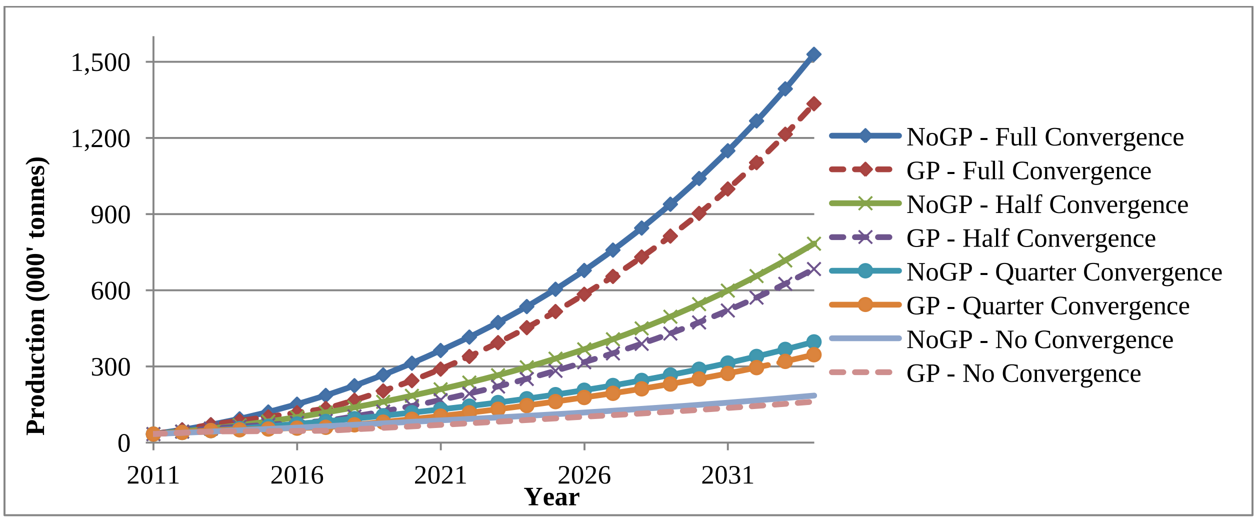

Figure 5.3 *No Genetic Protection* Case and *Genetic Protection* Case for Russia's Lentil Production for the Four Scenarios, 2011-2034

Source: Author's calculation

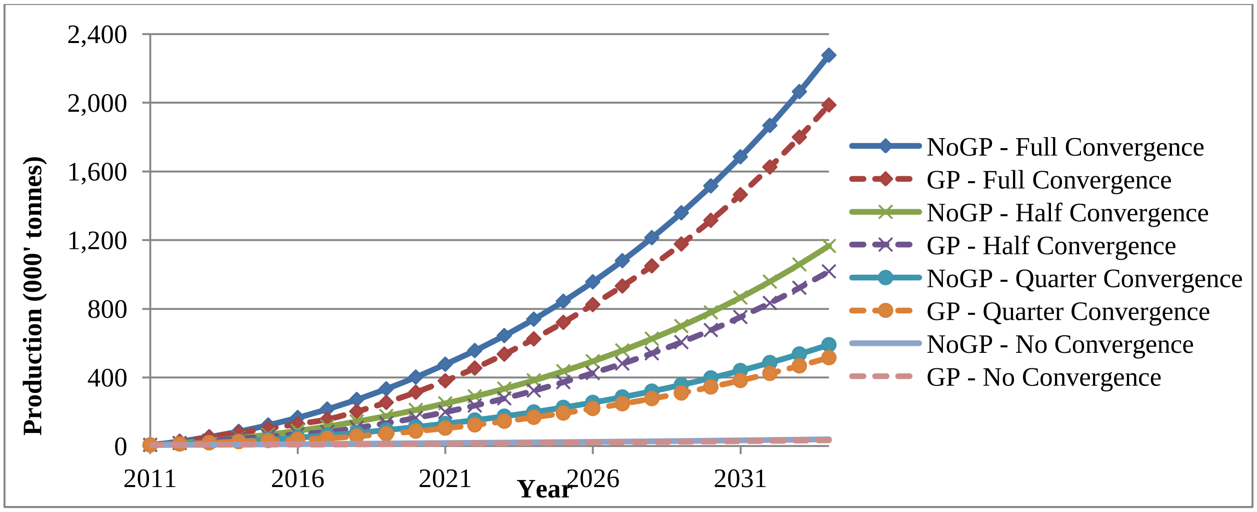

Figure 5.4 ***No Genetic Protection*** **Case and** ***Genetic Protection*** **Case for Kazakhstan's Lentil Production for the Four Scenarios, 2011-2034**

Source: Author's calculation

Table 5.3 Russia and Kazakhstan's Lentil Production for the *Full Convergence* Scenario, 2014-2034

Full Converge	*No Genetic Protection*		*Genetic Protection*		*Impact of Genetic Protection*	
Tonnes	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**
Year	**Russia**	**Kaz.**	**Russia**	**Kaz.**	**Russia**	**Kaz.**
2011	33.45	7.06	33.45	7.06	0.00	0.00
2012	50.14	28.11	49.94	28.00	0.20	0.11
2013	70.09	54.30	70.09	54.30	0.00	0.00
2014	93.48	85.92	85.35	78.44	8.14	7.48
2015	120.46	123.26	101.16	103.51	19.30	19.75
2016	151.16	166.54	117.55	129.51	33.61	37.03
2017	185.67	215.97	134.52	156.47	51.15	59.49
2018	224.07	271.68	166.80	202.24	57.27	69.44
2019	266.40	333.79	203.28	254.71	63.12	79.08
2020	312.66	402.33	244.12	314.13	68.54	88.20
2021	362.83	477.29	289.42	380.72	73.41	96.56
2022	415.55	556.87	339.26	454.64	76.29	102.23
2023	473.11	644.13	393.68	535.99	79.43	108.14
2024	535.83	739.55	452.69	624.80	83.14	114.75
2025	604.03	843.69	516.24	721.06	87.79	122.63
2026	678.08	957.09	584.25	824.66	93.82	132.43
2027	758.33	1,080.37	654.66	932.68	103.67	147.69
2028	845.18	1,214.14	730.97	1,050.07	114.21	164.07
2029	939.04	1,359.07	813.54	1,177.44	125.50	181.63
2030	1,040.34	1,515.87	902.77	1,315.42	137.57	200.45
2031	1,149.54	1,685.26	999.07	1,464.67	150.47	220.59
2032	1,267.12	1,868.03	1,102.87	1,625.89	164.25	242.14
2033	1,393.60	2,065.00	1,214.64	1,799.82	178.96	265.18
2034	1,529.50	2,277.03	1,334.84	1,987.24	194.65	289.79

Source: Author's calculation

Table 5.4 Russia and Kazakhstan's Lentil Production for the *No Convergence* Scenario, 2014-2034

No Converge	*No Genetic Protection*		*Genetic Protection*		*Impact of Genetic Protection*	
Tonnes	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**
Year	**Russia**	**Kaz.**	**Russia**	**Kaz.**	**Russia**	**Kaz.**
2011	33.45	7.06	33.45	7.06	0.00	0.00
2012	38.08	8.04	37.92	8.00	0.15	0.03
2013	42.91	9.06	42.91	9.06	0.00	0.00
2014	47.93	10.12	43.76	9.24	4.17	0.88
2015	53.14	11.21	44.62	9.42	8.51	1.80
2016	58.50	12.35	45.49	9.60	13.01	2.75
2017	64.01	13.51	46.38	9.79	17.63	3.72
2018	69.64	14.70	51.84	10.94	17.80	3.76
2019	75.38	15.91	57.52	12.14	17.86	3.77
2020	81.19	17.14	63.39	13.38	17.80	3.76
2021	87.06	18.37	69.44	14.66	17.61	3.72
2022	92.66	19.56	75.65	15.97	17.01	3.59
2023	98.54	20.80	81.99	17.31	16.54	3.49
2024	104.69	22.10	88.45	18.67	16.24	3.43
2025	111.14	23.46	94.99	20.05	16.15	3.41
2026	117.89	24.88	101.58	21.44	16.31	3.44
2027	124.96	26.37	107.88	22.77	17.08	3.61
2028	132.37	27.94	114.48	24.16	17.89	3.78
2029	140.11	29.57	121.39	25.62	18.73	3.95
2030	148.22	31.28	128.62	27.15	19.60	4.14
2031	156.71	33.08	136.20	28.75	20.51	4.33
2032	165.59	34.95	144.12	30.42	21.46	4.53
2033	174.88	36.91	152.42	32.17	22.46	4.74
2034	184.59	38.96	161.10	34.00	23.49	4.96

Source: Author's calculation

5.4 Results for Canadian Price, Production and Welfare Impacts When There is *No Genetic Protection* and When There is *Genetic Protection* for Canadian Red Lentil Varieties

This section breaks down further into three subsections, price effects, production effects, and welfare impacts. Each sub section will show the results for when there is *noGP* for CRL varieties and the results for when there is *GP* for CRL varieties.

5.4.1 Price Effects Over Time

World lentil prices will change over time because world supply and world demand changes for every year and in every scenario. The simulation model finds the equilibrium price, where world supply is equal to world demand. The simulation model in Chapter Four (Section 4.2) described how prices were calculated. These equilibrium prices are reported below.

5.4.1.1 Full convergence

In 2014,under the *full convergence* scenario for when there is *noGP*, world lentil prices will be $566.11 per tonne, and when *GP* for lentils occurs world lentil price will be $566.55 per tonne. In 2024 world prices in the *noGP* case will be $506.73 per tonne. When there is *GP*, world lentil prices will be increased to $510.51 per tonne. World lentil prices for 2034 in the *noGP* case will be set at $442.73 per tonne, where as in the *GP* case world prices will be set at $448.65 per tonne. As the lentil industries in Russia and Kazakhstan expand production, the benefits received from protecting lentils through *GP* increase. The impacts to world lentil price for the *full convergence* and the other scenarios are shown in Figure 5.5. World lentil prices for *full convergence* are found in Table 5.5.

5.4.1.2 Half convergence

For the *half convergence* scenario in 2014, world price for lentils will be set at $567.60 per tonne when there is *noGP*. When there is *GP* for lentils, world lentil price will be set at $567.89. In 2024, world price will be $518.81 per tonne with *GP* and $516.64 per tonne with *noGP*. For 2034, world price of lentils will fall to $462.64 per tonne when there is *noGP*, and with *GP* world prices will be $466.18. Like in the *full convergence* scenario, in the *half convergence* scenario, the lentil price effect will get larger as Russia and Kazakhstan's lentil industries increase production.

5.4.1.3 Quarter Convergence

In 2014, when Russia and Kazakhstan converge a quarter of the way to the Canadian spring wheat hectares, world price for lentils will be $568.45 per tonne when *noGP* is in place. When there is *GP* for lentil varieties, prices will increase to $568.66 per tonne. In 2024, when there is *noGP* for lentils, world price will be set at $522.26 per tonne and when there is *GP* for lentil varieties, prices will be set at $523.50 per tonne. In 2034, when *noGP* is in place for Canadian lentils, world lentil price will be $474.81 per tonne, and when there is *GP* world price will be $476.77 per tonne. The world lentil price impacts are shown in Figure 5.5. World lentil prices for the *half convergence* and the *quarter convergence* are found in Appendix C, Table C3.

5.4.1.4 No convergence

For the *no convergence* scenario, in 2014 world price for lentils will be set at $569.12 per tonne when there is *noGP*. When there is *GP*, world prices will be set at $569.27 per tonne. For 2024, world price for lentils will be $526.86 per tonne when there in *noGP* for lentils and when there is *GP* world price will be $527.38 per tonne. In 2034, world price for lentils will be set at $485.43 per tonne when there is *noGP* for Canadian lentils, but when there is *GP* for Canadian lentils, world price will be set at $486.01 per tonne.

Figure 5.5 shows that in time the impacts of *GP* of lentil varieties will increase, and that the price change is getting larger with time. The larger the lentil industry in Russia and Kazakhstan, the larger impact will be on the price change. The price effects are noticeably larger in the *full convergence* scenario compared to the *no convergence* scenario. This occurs because when Russia and Kazakhstan expand their lentils industry they increase the world supply of lentils, therefore decreasing world price. As illustrated in Figure 5.5, the price impacts over time are nonlinear and this occurs because of the annual yield growth rates. As described in Chapter Four, the annual yield growth rates for CRL varieties will decrease from three percent down to two percent over time. The results for the price effects are shown in Table 5.5. When Russia and Kazakhstan adopt the CRL varieties, the global supply of lentils will increase, therefore having a negative effect on global prices.

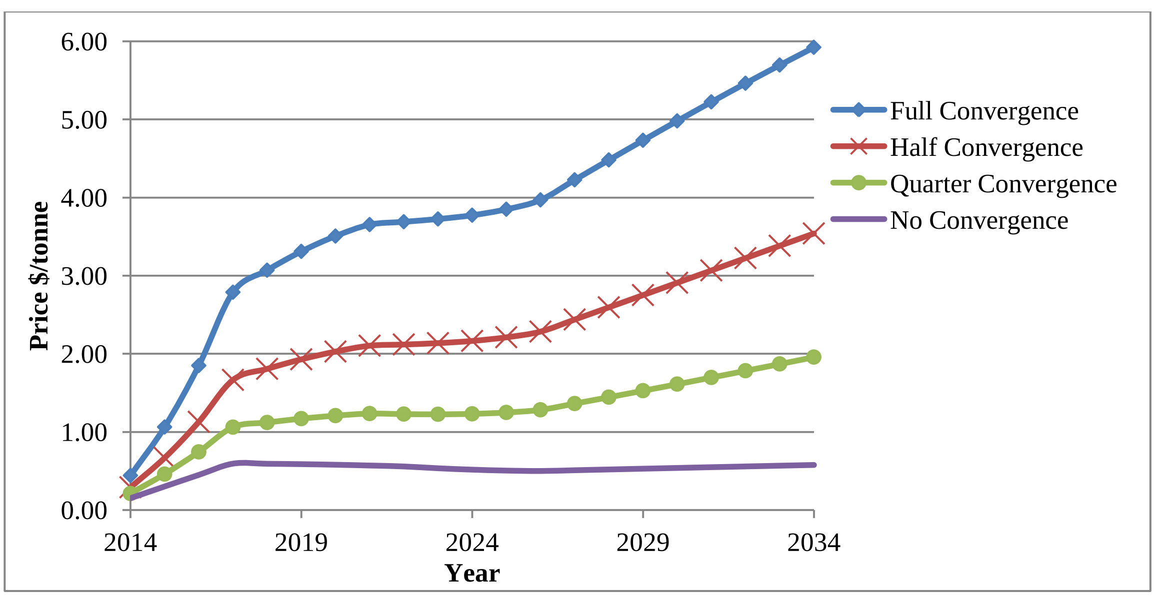

Figure 5.5 Price Impact of *Genetic Protection* of Canadian Lentil Varieties, 2014-2034
Source: Author’s calculation

Table 5.5 Lentil Price Impacts in the *Full Convergence* Scenario and the *No Convergence* Scenario, 2014-2034

	Full Convergence			***No Convergence***		
	No Genetic Protection	***Genetic Protection***	**Impact of *GP***	***No Genetic Protection***	***Genetic Protection***	**Impact of *GP***
Year	**Price $/tonne**	**Price $/tonne**	**Price Affects $/tonne**	**Price $/tonne**	**Price $/tonne**	**Price Affects $/tonne**
2014	566.11	566.55	0.44	569.12	569.27	0.15
2015	560.28	561.35	1.06	564.60	564.90	0.30
2016	554.36	556.21	1.85	560.11	560.56	0.45
2017	548.38	551.16	2.79	555.66	556.26	0.59
2018	542.35	545.42	3.07	551.27	551.87	0.59
2019	536.30	539.62	3.31	546.96	547.54	0.59
2020	530.27	533.78	3.51	542.72	543.30	0.58
2021	524.27	527.93	3.65	538.58	539.16	0.57
2022	518.53	522.22	3.69	534.70	535.26	0.56
2023	512.68	516.41	3.73	530.80	531.34	0.54
2024	506.73	510.51	3.77	526.86	527.38	0.52
2025	500.69	504.54	3.85	522.89	523.39	0.51
2026	494.55	498.52	3.97	518.87	519.37	0.50
2027	488.32	492.55	4.23	514.82	515.33	0.51
2028	482.01	486.49	4.48	510.73	511.25	0.52
2029	475.63	480.36	4.73	506.60	507.13	0.53
2030	469.17	474.15	4.98	502.44	502.98	0.54
2031	462.64	467.87	5.22	498.24	498.79	0.55
2032	456.06	461.52	5.46	494.01	494.57	0.56
2033	449.42	455.11	5.70	489.74	490.30	0.57
2034	442.73	448.65	5.92	485.43	486.01	0.58

Source: Author's calculation

5.4.2 Canadian Lentil Production Affects Over Time

In this thesis Canadian lentil production will change every year, and with each scenario, due to the changes in world lentil prices. World lentil prices will vary depending on the quantity of lentils that each country produces, and the price of other crops. An assumption of this thesis is that the price of other crops will stay relatively constant. This section will show Canadian lentil production for the four scenarios of convergences for Russia and Kazakhstan. This section will also compare how much Canadian producers will produce based on when there is *noGP* for lentils or when Canadian firms protect IP through *GP*.

5.4.2.1 Full Convergence

In the *full convergence* scenario, when there is *noGP* for CRL varieties, in 2014 Canadian lentil producers will produce 1.511 million tonnes of lentils. In 2014, lentil production for Canadian producers will increase to 1.516 million tonnes of lentils if Canadian firms *genetically protect* their lentil varieties. Canadian lentil production in 2024, when there is *noGP*, will be 2.085 million tonnes of lentils, and when lentils are *genetically protected*, production will be 2.133 million tonnes of lentils. For 2034, when there is *noGP* for lentils, 2.568 million tonnes of lentils will be produced. When there is *GP* for lentils, Canadian producers will produce 2.670 million tonnes of lentils. As the lentil industries in Russia and Kazakhstan expand production, the benefits received from protecting lentils through *GP* increase. Canadian lentil producers expand their lentil production when Russia and Kazakhstan do not have access to the new CRL varieties. Canadian lentil production for *full convergence* and the other scenarios are shown in Figure 5.6.

5.4.2.2 Half Convergence

For the *half convergence* scenario in 2014, Canadian lentil producers will produce 1.529 million tonnes of lentils when there is *noGP*. Production will increase to 1.532 million tonnes when lentils are *genetically protected.* In 2024, 2.218 million tonnes of lentils will be produced in Canada when there is *noGP*, and when there is *GP*, 2.245 million tonnes of lentils will be produced. For 2034, Canadian producers will produce 2.919 million tonnes of lentils when *noGP* occurs. When *GP* occurs, Canadian producers will produce 2.980 million tonnes of lentils. The difference in the amount of lentils produced from 2014 to 2034 with *noGP* and *GP* is shown in Figure 5.6, which demonstrates that as Russia and Kazakhstan increase their lentil industry, Canadian lentil producers will produce more when their CRL varieties are *genetically protected*. Refer to Appendix C, Table C4 to see Canadian lentil production for the *half convergence* scenario from 2014 to 2034.

5.4.2.3 Quarter Convergence

For the *quarter convergence* scenario in 2014, Canadian production of lentils will be 1.537 million tonnes of lentils when there is *noGP*. When there is *GP* for lentils, Canadian production will be 1.539 million tonnes of lentils. In 2024, Canadian production will be 2.306 million tonnes of lentils with *GP* and 2.290 million tonnes of lentils with *noGP*. For 2034, Canadian lentil producers will produce 3.129 million tonnes of lentils when there is *noGP* and with *GP* producers will produce 3.163 million tonnes of lentils. Refer to Appendix C, Table C4 to see Canadian lentil production for the *quarter convergence* scenario from 2014 to 2034.

5.4.2.4 No convergence

In the *no convergence* scenario, when there is *noGP* for CRL varieties, Canadian lentil producers will produce 1.543 million tonnes of lentils. In 2014, lentil production for Canadian producers will increase to 1.545 million tonnes of lentils if Canadian firms *genetically protected* lentil varieties. Canadian lentil production in 2024 when there is *noGP* will be 2.349 million tonnes of lentils. When lentils are *genetically protected,* production will be 2.355 million tonnes of lentils. For 2034, when there is *noGP*, 3.312 million tonnes of lentils will be produced and when there is *GP* for lentils, Canadian producers will produce 3.322 million tonnes of lentils. Canadian lentil production for *no convergence* and the other scenarios are shown in Figure 5.6.

As production of lentils expands in Russia and Kazakhstan, the benefits received from protecting lentils through *GP* increase. Canadian lentil producers expand their lentil production when Russia and Kazakhstan do not have access to the new CRL varieties. The impact to Canadian lentil producers' production is larger in the *full convergence* scenario compared to the *no convergence* scenario; this is shown in Figure 5.6. In the *full convergence* scenario, Russia and Kazakhstan have a larger lentil industry and therefore will have large impacts on the Canadian lentil industry. In the *no convergence* scenario, Russia and Kazakhstan will have little impact on the world market and therefore little impact on the Canadian lentil market. As illustrated in Figure 5.6, the Canadian lentil production impacts over time are nonlinear, similar to the lentil price impacts. This occurs because of the changing annual yield growth rates, which are described in Chapter Four.

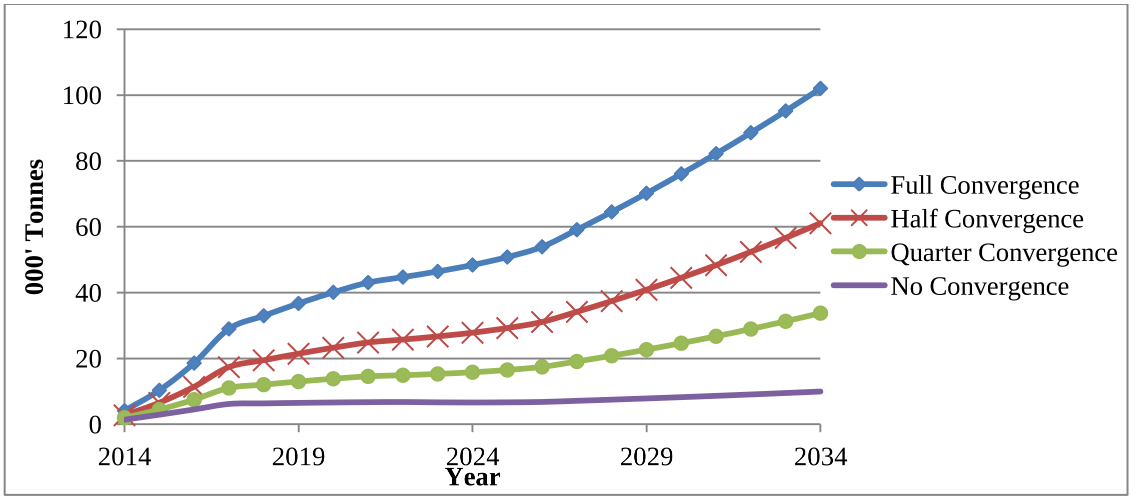

Figure 5.6 Canadian Production Impacts Over Time of *Genetic Protection* of Canadian Lentil Varieties, 2014-2034

Source: Author's calculation

Table 5.6 Canadian Production Impacts in the *Full Convergence* Scenario and the *No Convergence* Scenario, 2014-2034

	Full Convergence			*No Convergence*		
	No Genetic Protection	*Genetic Protection*	Impact of *GP*	*No Genetic Protection*	*Genetic Protection*	Impact of *GP*
Year	Tonnes (000'000')	Tonnes (000'000')	Tonnes (000')	Tonnes (000'000')	Tonnes (000'000')	Tonnes (000')
2014	1.51	1.52	4.14	1.54	1.54	1.43
2015	1.58	1.59	10.32	1.62	1.63	2.95
2016	1.64	1.66	18.59	1.70	1.71	4.54
2017	1.70	1.73	28.98	1.78	1.79	6.19
2018	1.77	1.80	32.97	1.87	1.87	6.37
2019	1.83	1.86	36.71	1.95	1.95	6.53
2020	1.88	1.92	40.10	2.03	2.04	6.65
2021	1.94	1.98	43.06	2.11	2.12	6.73
2022	1.99	2.03	44.72	2.19	2.19	6.78
2023	2.04	2.08	46.44	2.27	2.27	6.68
2024	2.08	2.13	48.40	2.35	2.36	6.65
2025	2.13	2.18	50.81	2.43	2.44	6.68
2026	2.18	2.24	53.92	2.52	2.53	6.81
2027	2.23	2.29	59.10	2.61	2.62	7.15
2028	2.28	2.35	64.52	2.70	2.71	7.50
2029	2.33	2.40	70.17	2.80	2.80	7.87
2030	2.38	2.45	76.07	2.89	2.90	8.25
2031	2.43	2.51	82.20	2.99	3.00	8.65
2032	2.47	2.56	88.58	3.10	3.11	9.07
2033	2.52	2.62	95.18	3.20	3.21	9.51
2034	2.57	2.67	102.03	3.31	3.32	9.97

Source: Author’s calculation

5.4.3 Welfare Impacts for Canadian Lentil Producers Over Time

This section will determine the impact that *GP* of new CRL varieties will have on Canadian welfare. Welfare impacts will vary, depending on the scenario and on the year, because welfare impacts will depend on the world lentil price and the amount of lentils Canadian producers grow.

5.4.3.1 Full Convergence

In the *full convergence* scenario, when there is *noGP* for CRL varieties, the discounted producer surplus (PS) for Canadian lentil producers will be $115.83 million in 2014. The discounted producer surplus is the 2034 price, which has been discounted to the present value. In the *full convergence* scenario, when there is *GP* for CRL varieties, discounted PS for Canadian lentil producers will be $116.47 million. In 2024, Canadian lentil producers will receive $99.07 million in surplus when there is *noGP* for lentils and when lentils are *genetically protected* producer surplus will be $103.73 million. In 2034, PS will be $68.73 million for Canadian lentil producers when there is *noGP* and when there is *GP,* PS will be $74.30 million. The annual additional PS that is gained by Canadian producers is shown in Figure 5.7 and is seen in Table 5.7. In the *full convergence* scenario when Russia and Kazakhstan's lentil industry get larger, more surplus is gained for Canadian lentil producers when they *genetically protect* their CRL varieties.

From 2014 to 2034 the net total amount of discounted PS Canadian lentil producers will receive is $2.04 billion when there is *noGP*. With *GP* the total discounted PS Canadian lentil producers receive is $2.13 billion from 2014 to 2034. From 2014 to 2034 a net total of $92.67 million in additional PS is gained when *GP* is in place for lentils. Table 5.8 shows the total discounted PS for every year in the *full convergence* scenario. The $92.67 million increase in PS from *GP* of lentils varieties will be equivalent to an average of $7.14 per tonne per year more for lentils over the twenty years.

5.4.3.2 Half Convergence

Under the *half convergence* scenario in 2014, when there is *noGP,* Canadian lentil producers will receive $118.43 million in PS. When there is *GP* for lentils, they will receive $118.85 million in PS. When there is *noGP* for Canadian lentils, producers in Canada will get $111.96 million in surplus in 2024. When there is *GP* for Canadian lentils, producers in Canada will get $114.78 million in surplus. Producer surplus for Canadian lentil producers in 2034 will be $88.67 million when there is *noGP*. Producer surplus for Canadian lentil producers in 2034 will be $92.42 million when *GP* occurs for CRL varieties.

The net total amount of discounted PS Canadian lentil producers will receive from 2014 to 2034 in the *half convergence* scenario is $2.29 billion when there is *noGP*. When there is *GP*, the total discounted PS Canadian lentil producers receive is $2.35 billion from 2014 to 2034. From 2014 to 2034, a net total of $57.93 million in additional PS is gained when *GP* is in place for lentils. This will be equal to an average of $4.25 per tonne per year of additional PS for Canadian lentil producers when they use *GP* for their lentils varieties over the twenty years.

5.4.3.3 Quarter Convergence

In the *quarter convergence* scenario, when there is *noGP* for CRL varieties, discounted PS for Canadian lentil producers will be $119.66 million in 2014. In 2014, when there is *GP* for CRL varieties, discounted PS for Canadian lentil producers will be $119.97 million. In 2024, Canadian lentil producers will receive $119.36 million in surplus when there is *noGP* for lentils. When lentils are *genetically protected* in 2024, PS will be $121.02 million. In 2034, for the *quarter convergence* scenario, PS will be $101.88 million for Canadian lentil producers when there is *noGP.* When there is *GP,* PS will be increased to $104.09 million. In the *quarter convergence* scenario, when Russia and Kazakhstan's lentil industry get larger, more surplus is gained for Canadian lentil producers when they *GP* their CRL varieties. Annual Canadian welfare impacts in the *half convergence* scenario and the *quarter convergence* scenario can be seen in Appendix C, Table C5.

The net total amount of discounted PS Canadian lentil producers will receive from 2014 to 2034 is $2.45 billion when there is *noGP.* When there is *GP* for CRL varieties, the total discounted PS Canadian lentil producers receive is $2.48 billion from 2014 to 2034. From 2014 to 2034, a total of $34.60 million in additional PS is gain when *GP* is in place for lentils. Net total welfare is shown for every year in the *half convergence* and the *quarter convergence* scenario in Appendix C, Table C6. The $34.60 million increase in PS from *GP* of lentils varieties will be equivalent to $2.47 per tonne per year more for lentils over the twenty years.

5.4.3.4 No Convergence

For the no *convergence* scenario in 2014 when there is *noGP,* Canadian lentil producers will receive $120.64 million in PS. When there is *GP,* they will receive $120.86 million in PS. When there is *noGP* for CRL varieties, producers in Canada will get $125.60 million in surplus in 2024. When there is *GP* for CRL varieties, producers in Canada will get $126.31 million in PS. In 2034, PS for Canadian lentil producers will be $114.15 million when there is *noGP*. When *GP* occurs PS for Canadian lentil producers in 2034 will be $114.84 million.

The net total amount of discounted PS Canadian lentil producers will receive from 2014 to 2034 in the *no convergence* scenario is $2.58 billion when there is *noGP*. When there is *GP,* the total discounted PS Canadian lentil producers receive is $2.60 billion from 2014 to 2034. From 2014 to 2034, a total of $14.65 million in additional discounted PS is gained when *GP* is in place for lentils. Total discounted PS is shown for every year in the *no convergence* scenario in

Table 5.8. This will be equal to $0.74 per tonne per year of additional PS for Canadian lentil producers when they use *GP* for their lentils varieties for 2014 to 2034.

Figure 5.7 shows that as Russia and Kazakhstan increase their lentil production, there is greater opportunity for Canadian lentil producers to benefit by protecting the IP of CRL varieties. When Canadian lentils are *genetically protected*, world lentil prices fall at a slower rate, Canadian lentil producers will produce a larger amount of lentils and Canadian lentil producers will receive addition PS. The impacts that result from Canadian lentils being *genetically protected* are greater when Russia and Kazakhstan's lentil industries are more established. For example, Canadian lentil producers will gain more additional PS by *genetically protecting* lentils in the *full convergence* scenario compared to the *no convergence* scenario.

Like the treadmill theory indicates, as others countries adopt the new CRL varieties, global production of lentils will increase, leading to a decrease in world lentil prices, which therefore reduces economic welfare for Canadian lentil producers. If Russia and Kazakhstan *fully convergence* the impacts of the treadmill effect will be more than if they were to have a *no convergence* scenario.

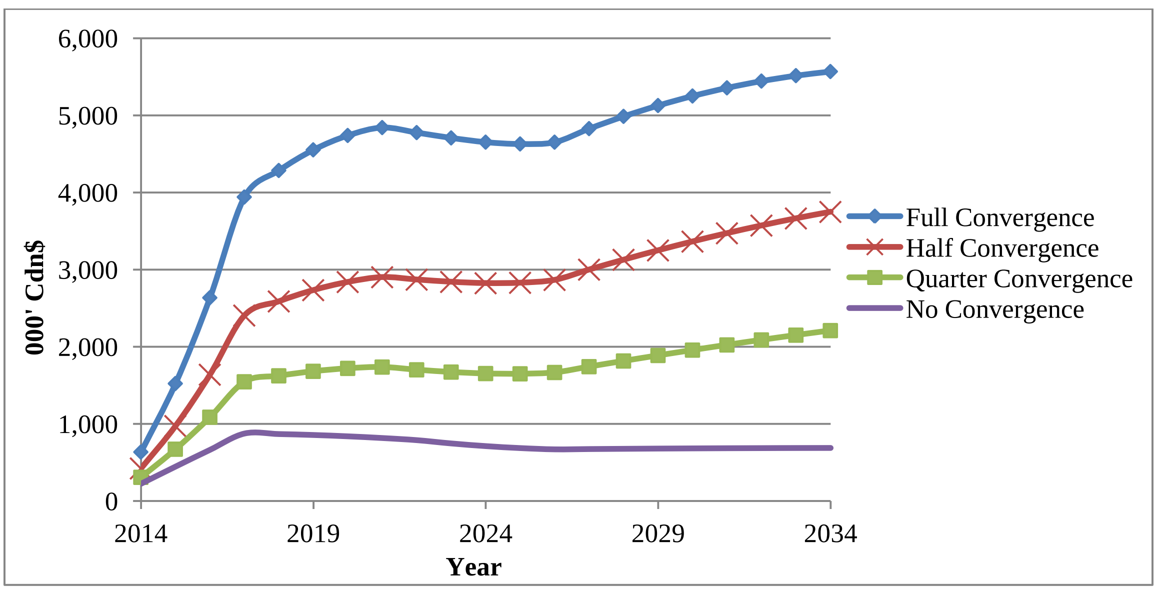

Figure 5.7 Annual Canadian Welfare Impacts Over Time of *Genetic Protection* of Canadian Lentil Varieties, 2014-2034
Source: Author's calculation

Table 5.7 Annual Canadian Welfare Impacts in the *Full Convergence* Scenario and the *No Convergence* Scenario, 2014-2034

	Full Convergence			***No Convergence***		
	No Genetic Protection	***Genetic Protection***	**Impact of GP**	***No Genetic Protection***	***Genetic Protection***	**Impact of GP**
	(000'000')	**(000'000')**	**(000')**	**(000'000')**	**(000'000')**	**(000')**
Year	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**
2014	115.83	116.47	635.74	120.64	120.86	224.23
2015	116.02	117.55	1,523.63	122.73	123.17	446.22
2016	115.72	118.36	2,636.18	124.47	125.13	663.80
2017	114.94	118.88	3,941.93	125.85	126.73	874.89
2018	113.72	118.00	4,286.01	126.87	127.74	868.12
2019	112.08	116.63	4,553.74	127.53	128.39	856.02
2020	110.07	114.81	4,740.10	127.83	128.67	838.75
2021	107.71	112.56	4,842.50	127.77	128.59	816.54
2022	104.90	109.67	4,777.29	127.10	127.89	789.04
2023	102.01	106.72	4,708.24	126.39	127.13	746.33
2024	99.07	103.73	4,653.49	125.60	126.31	711.88
2025	96.09	100.72	4,629.98	124.74	125.43	686.24
2026	93.06	97.72	4,653.14	123.82	124.49	669.90
2027	90.02	94.85	4,828.89	122.83	123.50	673.63
2028	86.95	91.94	4,987.41	121.77	122.45	676.95
2029	83.88	89.01	5,128.41	120.65	121.33	679.86
2030	80.81	86.07	5,251.73	119.47	120.15	682.35
2031	77.76	83.11	5,357.34	118.23	118.91	684.40
2032	74.72	80.16	5,445.30	116.92	117.61	686.02
2033	71.71	77.22	5,515.79	115.57	116.25	687.20
2034	68.73	74.30	5,569.09	114.15	114.84	687.93

Source: Author’s calculation

Table 5.8 Net Total Canadian Welfare Impacts in the *Full Convergence* Scenario and the *No Convergence* Scenario, 2014-2034

	Full Convergence			*No Convergence*		
	No Genetic Protection	*Genetic Protection*	Impact of *GP*	*No Genetic Protection*	*Genetic Protection*	Impact of *GP*
	(000'000')	(000'000')	(000'000')	(000'000')	(000'000')	(000'000')
Year	Discounted PS Cdn$	Discounted PS Cdn$	Discounted PS Cdn$	Discounted PS Cdn$	Discounted PS Cdn$	Discounted PS Cdn$
2014	115.83	116.47	0.64	120.64	120.86	0.22
2015	231.85	234.01	2.16	243.37	244.04	0.67
2016	347.58	352.37	4.80	367.84	369.17	1.33
2017	462.52	471.26	8.74	493.69	495.90	2.21
2018	576.24	589.26	13.02	620.56	623.64	3.08
2019	688.32	705.89	17.58	748.09	752.02	3.93
2020	798.38	820.70	22.32	875.92	880.69	4.77
2021	906.10	933.26	27.16	1,003.69	1,009.28	5.59
2022	1,010.99	1,042.93	31.94	1,130.79	1,137.17	6.38
2023	1,113.01	1,149.65	36.65	1,257.17	1,264.30	7.12
2024	1,212.08	1,253.38	41.30	1,382.77	1,390.61	7.84
2025	1,308.17	1,354.10	45.93	1,507.52	1,516.04	8.52
2026	1,401.23	1,451.82	50.58	1,631.34	1,640.53	9.19
2027	1,491.25	1,546.66	55.41	1,754.17	1,764.03	9.87
2028	1,578.20	1,638.60	60.40	1,875.94	1,886.48	10.54
2029	1,662.08	1,727.61	65.53	1,996.59	2,007.82	11.22
2030	1,742.90	1,813.68	70.78	2,116.06	2,127.97	11.90
2031	1,820.65	1,896.79	76.14	2,234.29	2,246.88	12.59
2032	1,895.37	1,976.95	81.58	2,351.22	2,364.49	13.28
2033	1,967.08	2,054.18	87.10	2,466.78	2,480.74	13.96
2034	2,035.81	2,128.48	92.67	2,580.93	2,595.58	14.65

Source: Author's calculation

5.5 Welfare Impacts for Russia, Kazakhstan, ROW, and the Global Lentil industry

Russia, Kazakhstan, ROW, and the global lentil industry will be affected if *GP* for CRL varieties occurs. Welfare received for lentil producers in Russia and Kazakhstan will be reduced if Canadian firms use *GP* to protect their lentil varieties. The loss in welfare for lentil producers in Russia and Kazakhstan will vary depending on the scenarios. For Russia, their welfare could be reduced from \$27.98 to 88.56 million in PS when there is *no convergence* to *full convergence,* from 2014 to 2034. From 2014 to 2034 for Kazakhstan, their welfare could be reduced by \$5.91 million when there is *no convergence,* and when there is *full convergence,* \$119.83 million is lost in PS. Russia and Kazakhstan are greatly impacted when Canadian firms use *GP* for their lentils, larger impacts occur to Russia and Kazakhstan when they have grown their lentils industries to *full convergence* compared to when *no convergence* takes place.

When *GP* occurs for CRL varieties, ROW will benefit because they will have increasing welfare. The amount that welfare increases will depend on the scenarios that are examined. Increased welfare from 2014 to 2034 for ROW could vary from an additional $14.50 million when *no convergence* takes place, to an increase of $81.00 million when *full convergence* occurs. Lentil producers in ROW will have greater positive benefits when Russia and Kazakhstan convergence fully.

When *GP* for CRL varieties occurs, it has an overall negative impact on the global lentil market. Total welfare for world producers will be reduced in all of the scenarios provided in this thesis. When *no convergence* and *full convergence* occurs, welfare will be reduced from $4.74 million to $34.73 million from 2014 to 2034 for the world lentil industry. It also negatively impacts world consumers when *GP* for Canadian lentils occurs, because it reduces consumer surplus in the world lentil market. From 2014 to 2034, world consumer welfare could be reduced by a minimum of $29.67 million when *no convergence* takes place and a maximum of $212.63 million when *full convergence* takes place. The *full convergence* scenario will have the largest impact on the world lentil market because if Russia and Kazakhstan *fully convergence* to the relative size of the Canadian lentil market, they will be big players in the lentil market and therefore they will have large impacts on the world lentil market. Results of welfare impacts of Russia, Kazakhstan, ROW, and the world are shown in Table 5.9.

Table 5.9 The Global Net Welfare Impacts for the World When Canadian Firms Use *Genetic Protection* for Canadian Red Lentil Varieties, 2014-2034

	Full Convergence	***Half***	***Quarter***	***No Convergence***
	000'000'	**000'000'**	**000'000'**	**000'000'**
Country	**Discounted PS from 2014-2034 Cdn$**	**Discounted PS from 2014-2034 Cdn$**	**Discounted PS from 2014-2034 Cdn$**	**Discounted PS from 2014-2034 Cdn$**
Canada	92.67	57.93	34.60	14.65
Russia	-88.56	-57.67	-36.98	-27.98
Kazakhstan	-119.83	-72.77	-41.34	-5.91
ROW	81.00	52.06	32.00	14.50
World Producers	-34.73	-20.45	-11.72	-4.74
World Consumers	-212.63	-122.81	-70.62	-29.67

Source: Author’s calculation

5.6 Break Even Processing Margin

Thus far this thesis has demonstrated scenarios as if the *genetic protection* of CRL varieties were costless, and Canadian lentil producers would earn additional producer surplus by mitigating future competition from Kazakhstan and Russia. However, *GP* for lentils is a process that involves the de-hulling of all new CRL varieties before export. If this processing requirement increases the margin between the price received by Canadian farmers and the price paid by consumers, *GP* could come at a cost to Canadian lentils producers.

While determining the impact of *GP* on the processing margins is beyond the scope of this thesis, this section calculates the "break even increase" in the processing margin that would leave Canadian lentil producers indifferent to *GP*. The breakeven point is the additional margin where the profits earned by Canadian lentil producers will be equivalent to the profits earned when there is *noGP* for CRL varieties. If the additional processing cost is higher than the breakeven point, *GP* will result in lower producer surplus compared to *noGP*. When the processing cost is below the breakeven point, Canadian lentil producers will benefit from the *genetically protecting* their lentils.

The impact of *GP* and additional processing margins are shown in Figure 5.8. *GP* increases the demand for Canadian lentils from D_{noGP} to D_{GP}. The demand for Canadian lentils is brought on by the increased demand for lentil exports. The world lentil supply is reduced when lentils are *genetically protected*, which causes an increase in demand for lentils. If the processing margin did not change, *GP* would increase the farm price and production. If the processing margin also increases, this adds cost to Canadian production, reducing the quantity supplied and reducing the farm price by driving a wedge between the world price and the farm price. The break even additional margin, *M*, is shown in Figure 5.8. In this case, the additional processing margin just offsets the increase in the world price brought about by *GP*. In this case, the Canadian farm price and the quantity supplied remain unchanged from *noGP*. As constructed, the Canadian farmers breakeven from *GP*. If the increase in the margin is less than the increase in world price, farmers will gain from *GP*. If the increase in processing margin is greater than the increase in world price, *GP* could leave farmers worse off.

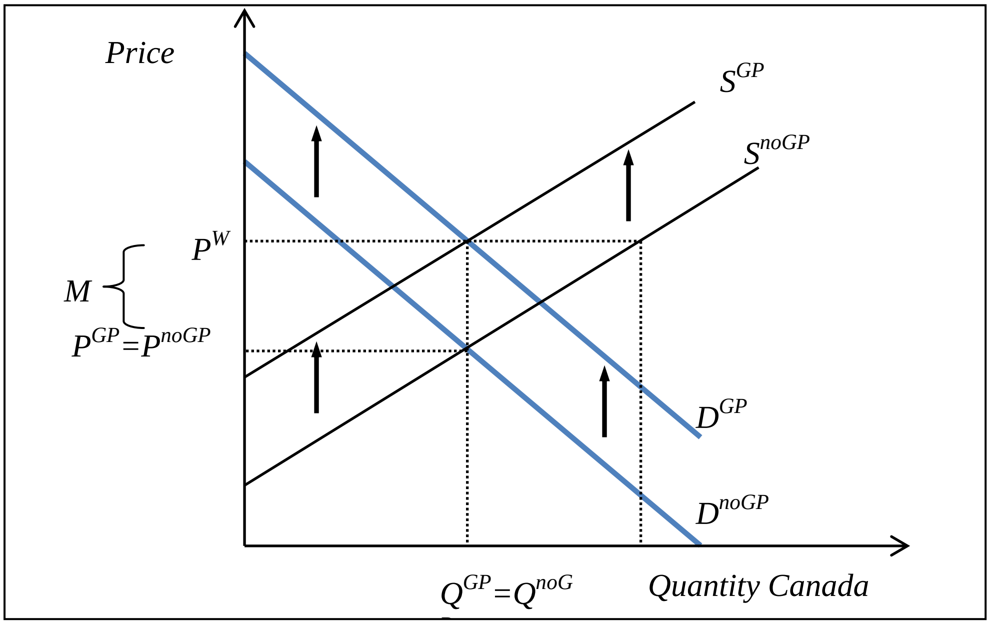

Figure 5.8 Breakeven Additional Processing Margin for Genetic Protection versus No Genetic Protection

A simulation model was used to calculate the breakeven increase in processing margins for each of the four convergence scenarios. Given the economic impacts that take place over a number of years, the breakeven processing margin is calculated as the additional margin where the present value of *GP* is equal to zero. In *the full convergence* scenario, the breakeven processing margin is calculated to be $7.14 per tonne. This implies the present value of benefits from *GP* would be zero if the *GP* increased the processing margin by $7.14 per tonne in the 2014 to 2034 period. In the *half convergence* scenario, the breakeven processing margin is $4.25 per tonne. When the processing margin is less than $4.25, it will be beneficial to Canadian lentil producers to *genetically protect* their new CRL varieties. In the *quarter convergence* scenario the break even processing margin is $2.47 per tonne. When the processing margin is larger than $2.47 per tonne, Canadian lentil producers are going to use *noGP* for their lentils, because their profits will be higher when they do not protect their lentil varieties. In the *no convergence* scenario, the breakeven processing margin is $.74 per tonne. Given the probabilities assigned to each scenario, the expected breakeven margin is $3.41 per tonne.

5.7 Overall Expected Economic Impacts for *No Genetic Protection* and *Genetic Protection*

To determine the overall expected economic impact for Canada, Kazakhstan, Russia, ROW and the world lentil industry in the time period from 2014 to 2034 a weighted average will be taken. To take a weighted average, the probability each scenario has of occurring needs to be estimated. The probability that each scenario has of occurring was obtained by a survey that was given to a number of experts in the lentil industry. Given in the survey was an explanation of the four scenarios which are described in Chapter Five, in Section 5.2. The survey that was given out is in Appendix B. Participants were asked to give a percentage of each of the four scenarios on the probability of the scenarios had of occurring. When added, the percentages would be equal to one hundred percent. The responses that were received from all of the surveys responses were averaged. The probability weights suggests it is twenty-four percent likely *full convergence* will occur, for *half convergence* it is twenty-three, for *quarter convergence* is eighteen percent and *no convergence* is thirty-five percent. The weighted average is taken for both cases, when there is *noGP* for Canadian lentils and when *GP* for Canadian lentils occurs. The overall expected economic impacts of each of the two cases are determined by taking the weighted average. Determining the overall expected economic impacts for both cases reveals the economic benefits or economic losses that occur when Canadian firms protect IP of CRL varieties through *GP*.

The overall expected economic impact that Canadian lentil producers will receive from 2014 to 2034 is $2.36 billion in the case where there is *noGP* for Canadian lentil varieties. When Canadian firms protect their CRL varieties through *GP*, they will receive $2.41 billion from 2014 to 2034. Canadian lentil producers benefit when their lentils are protected through *GP;* they will receive an additional $47.12 million in welfare from 2014 to 2034. The expected welfare impacts are shown in Table 5.10. For the overall expected economic impact, an additional profit of $3.41 per tonne is gained when there is no cost for processing CRL varieties. When there is *GP* for CRL varieties, the processing margin would have to be less than $3.41 per tonne for lentils for Canadian lentil producers to earn additional profits. If the processing margin is larger than $3.41, than Canadian lentil producers will be better off if *noGP* is used for the lentil varieties.

Lentil producers in Russia will receive $216.66 million in welfare in the time frame of 2014 to 2034 when *noGP* occurs for CRL varieties, but when *GP* takes place for Canadian lentils before export, welfare is reduced to $165.51 million, which is a $51.15 million reduction in welfare for Russia. For Kazakhstan, the expected welfare that they will receive when *noGP* occurs for CRL varieties is $247.66 million in PS from 2014 to 2034. When CRL varieties are protected through *GP* before export, Kazakhstan lentil producers will receive $192.38 million in surplus, which is a loss in welfare of $55.28 million. Surplus received by lentil producers in

ROW when *noGP* occurs for Canadian lentils will be $1.72 billion from 2014 to 2034, but when *GP* occurs for Canadian lentils, ROW will receive $1.76 billion in lentil producer surplus. This is an additional $41.31 million in lentil producer welfare for ROW from 2014 to 2034. Overall, the expected economic impact of providing *GP* for CRL varieties is shown in Table 5.10.

Producers in the world lentil market will have $4.54 billion in expected welfare from 2014 to 2034 when *noGP* for CRL varieties. When Canadian firms protect their CRL varieties through *GP*, expected welfare will be reduce to $4.52 billion for world lentil producers; this is a loss of $20 million in welfare. Lentil consumers all over the world will receive $23.29 billion from 2014 to 2034 in consumer surplus when *noGP* occurs for Canadian lentil varieties. When Canadian firms protect their newly developed CRL varieties through *GP* world lentil consumers' surplus will be reduced to $23.18 billion. Lentil consumers are also negatively affected when Canadian firms protect their CRL varieties through *GP*, for they will lose $102.86 million in consumer surplus from 2014 to 2034; this is shown in Table 5.10.

Table 5.10 Overall Expected Economic Impacts for Canada, Russia, Kazakhstan, ROW and the Global Lentil Market When Canadian Red Lentils are Protected Through *Genetic Protection* versus *No Genetic Protection*, 2014-2034

Overall Expected Economic Impact	***No Genetic Protection***	***Genetic Protection***	***Impact of GP***
Country	**Discounted PS 2014-2034 Cdn$(000'000')**	**Discounted PS 2014-2034 Cdn$(000'000')**	**Discounted PS 2014-2034 Cdn$(000'000')**
Canada	2,356.26	2,405.52	47.12
Russia	216.33	690.88	-51.15
Kazakhstan	242.24	835.50	-55.28
ROW	1,714.21	1,757.34	42.42
World Producers	4,529.04	4,521.86	-16.89
World Consumers	23,262.28	23,184.25	-102.86

Source: Author's calculation

5.8 Sensitivity Analysis

This thesis looks at the results of when there is *GP* for lentils to protect IP of the new CRL varieties for four years. A sensitivity analysis on the length of periods of *GP* on the new lentil varieties will take place, to ensure that all possible and logical future scenarios are considered for this thesis[4]. This will determine the degree to which the Canadian lentil market will change when *GP* of lentils are increased or decreased. There will be two different time frames that *GP* will occur for lentils; two years and eight years. The first sensitivity analysis will be the two year protection period; this is half of the time of the four year protection period, which was examined in the thesis. When new CRL varieties are *genetically protected* for two years instead of four years, additional profits earned by Canadian lentil producers are decreased. The overall expected discounted PS will be $22.15 million for 2014 to 2034, which is less than the $47.12 million that could be earned when there is four years of *GP* for lentils. When there is two years of protection of new lentil varieties, the overall expected breakeven processing margin will be $1.58 per tonne. The second protection period conducted is for eight years; this is double the period examined in this thesis. Increasing the *GP* of CRL varieties to eight years versus four years will increase profits earned by Canadian lentil producers to $92.91 million from 2014 to 2034. Overall expected processing margin will be $6.63 per tonne when the CRL varieties are *GP* for eight years, this is shown in Table 5.11.

Table 5.11 Overall Expected Economic Impacts for Canada in the Sensitivity Analysis for *Genetic Protection* versus *No Genetic Protection*, 2014-2034

Overall Expected Economic Impact	*No Genetic Protection*	*Genetic Protection*	Impact of *GP*	Breakeven Processing Margin
Genetic Protection for new Canadian red lentil varieties	Discounted PS 2014-2034 Cdn$(000)	Discounted PS 2014-2034 Cdn$(000)	Discounted PS 2014-2034 Cdn$(000)	Discounted Price 2014-2034 Cdn$/tonne
2 Years of *GP*	2,358,402,241	2,379,589,812	21,187,570	1.54
4 Years of *GP*	2,358,402,241	2,405,524,532	47,122,291	3.41
8 Years of *GP*	2,358,402,241	2,451,316,058	92,913,817	6.63

Source: Author's calculation

5.9 Summary

Chapter Five has discussed and presented the results from the empirical model. This chapter describes four scenarios for lentil production in Russia and Kazakhstan for 2014 to 2034. Using four scenarios allows the reader to see the impact that the different levels of lentil production in Russia and Kazakhstan will have on Canadian producers. The results present the four scenarios in the case where *noGP* for CRL varieties occur and the case where there is

[4] An infinite rise in the protection period was determined and profit earned by Canadian lentil producers was increased to $163.22 million for 2014 to 2034, which is equivalent to the overall expected breakeven processing margin of $11.47 per tonne.

protection for CRL varieties through *GP*. The price at which producers will be indifferent from using *noGP* for their lentils and using *GP* for their lentils is determined in this chapter. Chapter Five also looked at all possible future scenarios for the length of *GP* for lentils. The next chapter will summarize the relevant conclusions of the research thesis and offer suggestions for further research in lentil processing in order to protect IP of newly developed CRL varieties in Canada.

Chapter 6 - Conclusions

6.1 Summary of Conclusions

The main goal of this thesis was to quantify the overall economic impact of having a process to protect intellectual property rights (IPR) of new Canadian red lentil (CRL) varieties by using a form of *genetic protection* (*GP*) such as de-hulling the lentils before export. A dynamic, multi-country, multi-period, partial equilibrium model was used in the process to determine the effects of restricting access of Canadian varieties through a value chain that de-hulls all red lentil exports

Canadian lentil producers have increased their international competitiveness for the last forty years through check-off funded research and the development of new lentil varieties (Gray and Scott, 2003). The results show that the newly developed varieties are not the advantage for Canada in the lentil industry. The real competitive advantage for the Canadian lentil industry is the check-off funded research and development system. The check-off funded research and development system acts as the competitive advantage because it has allowed the industry to develop the knowledge and skills to continually grow the lentil industry, which has allowed them to stay ahead of the competition.

The check-off funded research and development system has allowed the industry to grow to the size it is today. The producer funded breeding program at the Crop Development Centre (CDC) at the University of Saskatchewan has become a source of rapid genetic advancement in lentils, particularly in CRL varieties, which has maintained a three percent annual yield increase over the past few years. The higher yields and increased disease resistance have been a by product of the competitive advantage that has been obtained and has been a source of a temporary competitive advantage to Canadian lentil producers, who have expanded production and lentil exports. The new varieties that are developed by the research and development system are considered a by product of the competitive advantage, they provide the industry with an advantage for a short period of time which is why they are considered a temporary competitive advantage.

The Canadian red lentil varieties are well adapted to large regions of Russia and Kazakhstan. Given the lack of effective intellectual property rights for the CRL varieties, Saskatchewan-bred lentil varieties can be imported and grown in Russia and Kazakhstan. Russia and Kazakhstan both have a large land area suitable for lentil production and given their similar growing season to Saskatchewan, both have the potential to grow large areas of CRL varieties. The foreign production from Saskatchewan varieties will directly compete with domestic production, eroding the temporary competitive advantage and resulting in lost economic welfare for Canadian lentil producers. When other countries grow CRL varieties, global production increases, prices fall, and therefore Canadian lentil producers lose economic welfare.

One option to prevent the loss of economic welfare for Canadian lentil producers, and the erosion of the temporary Canadian competitive advantage, would be to ship only de-hulled lentils to the final markets, instead of as whole seeds. De-hulling the lentils before export is a form of *GP*, which prevents other countries from planting the new CRL varieties, therefore other countries are not able to erode the temporary competitive advantage. Forms of protection such as patents[5] and hybrids[6] are not appropriate to lentils, therefore by using *GP* for the CRL varieties would provide protection for the intellectual property (IP) of the lentils. *GP* is potentially beneficial to Canadian lentil producers, because it will slow the rate at which world lentil price decreases, due to the slower rate at which world supply of lentils increases. *Genetically protecting* the CRL varieties before export will result in higher profits for Canadian lentil producers, assuming that lentil acreage is constant.

The rate of erosion of the temporary Canadian competitive advantage will depend on the size of the foreign industry and the rate of diffusion of Canadian varieties. Just like the innovation treadmill concept, the early adopters will receive additional profits when they adopt the CRL varieties. As other countries adopt the new CRL varieties, the additional profits are reduced and will eventually vanish because the world supply of lentils increases, causing world prices to fall. If adoption is rapid, the temporary Canadian competitive advantage will be quickly eroded.

Depending on the level of growth in the lentil industry for Russia and Kazakhstan, the next twenty years could have a large influence on the economic effects of *genetically protecting* new CRL varieties. Although these countries do not currently compete with Canada in the lentil market, they have the potential to compete. As Russia and Kazakhstan's lentil industries acquire the agronomic knowledge, machinery technology and infrastructure, their lentil industry will

[5] In Canada, non-transgenic, non-vegetatively produced plants are not patentable.

converge towards the Canadian lentil industries position, allowing them to become large competitors in the lentil industry. Four possible scenarios for the growth in Russia and Kazakhstan's lentil industries are used for this thesis. Growth ranges from *no convergence* to *full convergence*: *No convergence* is when both countries continue producing lentils on a constant amount of hectares from 2014 to 2034, *Full convergence* is when both countries will have an equivalent of five percent of their spring wheat hectares planted to lentils. If *no convergences* were to occur for Russia and Kazakhstan there would be little impact on the economic welfare of Canadian lentil producers to *genetically protecting* the CRL varieties, but if both countries were to reach *full convergence,* then there would be large impacts to economic welfare for Canadian lentil producers when they used *GP* to protect their new CRL varieties.

The most important finding of this thesis is that the *GP* of CRL varieties will result in modestly higher prices in the global lentil market over the next 20 years. The difference in the prices of the *noGP* case and the *GP* case gets larger as Russia and Kazakhstan go from *no convergence* to *full convergence*. The price impacts of *GP* in 2034 ranges from $0.52 per tonne increase with *no convergence* to $5.92 per tonne increase with *full convergence*. If the net processing margin is not increased, *GP* will produce a net present value of $2.41 billion over the 2014 to2034 period, suggesting modest returns from *GP*. When all four convergence scenarios are evaluated and weighted by probabilities from industry expectations, estimated overall expected economic impact for Canadian lentil producers from 2014 to 2034 will be $47.12 million in additional producer surplus (PS), which is equal to $3.41 per tonne.

Additional profits earned by Canadian lentil producers will ultimately depend on the price processors will charge to process the lentils. The breakeven processing margin will be the price that makes the producers profits from *genetically protecting* their lentils to be equal to profits earned when there is *noGP* for lentils. Under *full convergence* of Russia and Kazakhstan's lentil industries, the breakeven additional processing margin is $7.14 per tonne. Under most likely convergence rate, the breakeven processing margin is $3.41 per tonne.

6.2 Study Limitations

There are four limitations of this thesis. The first study limitation is that there are only four scenarios that were analyzed as a possible outcome for the lentil growth and development of

[6] Hybrid plants provide protection because they are sterile and will not reproduce unlike lentils which are a self-replicating plant (DeBeer, 2005).

the lentil industry in Russia and Kazakhstan for 2011 to 2034. Four scenarios were used because they provided a range of scenarios of nil, low, medium and high convergences.

The second limitation of this study is that in the model Russia and Kazakhstan grow their industries at the same rate and will grow them to an equivalent size. Both Russia and Kazakhstan are at different stages in the lentil industry as of 2011 and this is the way they will most likely stay during the next twenty years. For this thesis, both countries will converge to the equivalent size, which is based on the percentage of their spring wheat hectares. If Russia and Kazakhstan were to converge based on the different stages they were at in 2011, both countries lentil production would increase to different levels of convergence making the situation complex.

The third study limitation is that this thesis assumes that Russia and Kazakhstan will achieve the same yield growth rate for the new CRL varieties as Canadian lentil producers, whereas lower or higher annual yield growth rates might be obtained because of their different farming practices.

A fourth limitation to the study is the assumption that Russia and Kazakhstan are converging toward the 2011 Canadian lentil/wheat area rather than where the Canadian lentil/wheat area might be in 2034. This was done because Russia and Kazakhstan are in the beginning stages of developing their lentil industries and it will take them longer than twenty years to converge fully to the 2034 Canadian lentil industry.

6.3 Recommendations for Further Research

This thesis determines that there are minimal additional profits to be earned by Canadian lentil producers when there is *GP* for lentils, but does not determine if *GP* is a feasible operation. Further research into the feasibility of setting up and implementing a supply chain that uses *GP* to protect the IP of new CRL varieties will need to be examined. Important issues that would need to be determined would be: the capacity of the processing facilities and if they have the ability to de-hull that level of lentils, and the ability of everyone to cooperate as a team in the supply chain to prevent the supply chain from having leakages that allow the IP of the new lentil varieties to be obtain my other countries. If effective *GP* is unattainable, the potential additional profits will not be earned.

An additional area of study that is brought on from this thesis is how much value is added to lentils when they are de-hulled. De-hulling lentils is a value added process that adds values to the lentils, this thesis did not determine the increase in the value of the processed lentils. De-hulled lentils are desirable to some consumers and are therefore worth a higher price than whole lentils. By determining the additional value that is added when de-hulling lentils it could potentially increase the value of using *GP* to protect the CRL varieties.

Further research could also examine *GP* for other pulse crops and compare the results to these CRL results. This could include niche lentil varieties, for which contracted based *GP* might be more feasible.

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Appendix A

Table A1 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *Full Convergence* when there is *No Genetic Protection* for Canadian Red Lentils, 2011-2034

Full Convergences - No Genetic Protection												
	Slopes						Intercepts					
Year	Cdn Red	Cdn Green	Kaz	Rus	Row	Demand	Cdn Red	Cdn Green	Kaz	Rus	Row	Demand
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,648	-78,875	-6,710,104	6,829,495
2012	4,484	4,269	145	258	15,859	-5,278	-1,860,293	-1,815,141	-60,032	-107,080	-6,743,655	6,904,619
2013	4,757	4,311	263	340	16,018	-5,336	-1,916,102	-1,824,216	-105,987	-136,826	-6,777,373	6,980,570
2014	5,036	4,355	395	430	16,178	-5,395	-1,971,669	-1,833,337	-154,495	-168,096	-6,811,260	7,057,356
2015	5,322	4,398	540	528	16,340	-5,454	-2,026,876	-1,842,504	-205,527	-200,870	-6,845,316	7,134,987
2016	5,614	4,442	699	635	16,504	-5,514	-2,081,602	-1,851,717	-259,044	-235,118	-6,879,543	7,213,472
2017	5,909	4,487	872	750	16,670	-5,575	-2,135,723	-1,860,975	-314,994	-270,806	-6,913,940	7,292,820
2018	6,209	4,532	1,060	874	16,837	-5,636	-2,189,116	-1,870,280	-373,314	-307,889	-6,948,510	7,373,041
2019	6,510	4,577	1,261	1,007	17,006	-5,698	-2,241,655	-1,879,632	-433,930	-346,320	-6,983,253	7,454,144
2020	6,813	4,623	1,477	1,148	17,176	-5,761	-2,293,213	-1,889,030	-496,754	-386,040	-7,018,169	7,536,140
2021	7,116	4,670	1,707	1,298	17,348	-5,824	-2,343,664	-1,898,475	-561,689	-426,987	-7,053,260	7,619,038
2022	7,404	4,716	1,947	1,453	17,522	-5,888	-2,390,537	-1,907,967	-628,010	-468,629	-7,088,526	7,702,847
2023	7,703	4,764	2,203	1,618	17,698	-5,953	-2,438,348	-1,917,507	-696,758	-511,767	-7,123,969	7,787,578
2024	8,014	4,811	2,477	1,795	17,875	-6,019	-2,487,115	-1,927,095	-768,006	-556,442	-7,159,588	7,873,242
2025	8,338	4,860	2,769	1,983	18,054	-6,085	-2,536,857	-1,936,730	-841,824	-602,700	-7,195,386	7,959,847
2026	8,675	4,908	3,081	2,183	18,235	-6,152	-2,587,594	-1,946,414	-918,288	-650,585	-7,231,363	8,047,406
2027	9,025	4,958	3,414	2,396	18,418	-6,219	-2,639,346	-1,956,146	-997,474	-700,145	-7,267,520	8,135,927
2028	9,390	5,007	3,769	2,623	18,603	-6,288	-2,692,133	-1,965,926	-1,079,460	-751,427	-7,303,858	8,225,422
2029	9,769	5,057	4,146	2,865	18,789	-6,357	-2,745,976	-1,975,756	-1,164,327	-804,480	-7,340,377	8,315,902
2030	10,164	5,108	4,548	3,121	18,978	-6,427	-2,800,895	-1,985,635	-1,252,156	-859,355	-7,377,079	8,407,377
2031	10,574	5,159	4,976	3,394	19,168	-6,498	-2,856,913	-1,995,563	-1,343,033	-916,103	-7,413,964	8,499,858
2032	11,002	5,211	5,431	3,684	19,360	-6,569	-2,914,051	-2,005,541	-1,437,044	-974,777	-7,451,034	8,593,356
2033	11,446	5,263	5,914	3,991	19,554	-6,641	-2,972,332	-2,015,569	-1,534,278	-1,035,431	-7,488,289	8,687,883
2034	11,908	5,316	6,428	4,317	19,750	-6,714	-3,031,779	-2,025,646	-1,634,827	-1,098,122	-7,525,731	8,783,450

Source: Author's calculation

Table A2 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *Full Convergence* when there is *Genetic Protection* for Canadian Red Lentils, 2011-2034

Full Convergences - Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,648	-78,875	-6,710,104	6,829,495
2012	4,484	4,269	145	258	15,859	-5,278	-1,860,293	-1,815,141	-59,974	-106,977	-6,743,655	6,904,619
2013	4,757	4,311	263	340	16,018	-5,336	-1,916,102	-1,824,216	-105,987	-136,826	-6,777,373	6,980,570
2014	5,036	4,355	377	410	16,178	-5,395	-1,971,669	-1,833,337	-150,891	-164,176	-6,811,260	7,057,356
2015	5,322	4,398	493	481	16,340	-5,454	-2,026,876	-1,842,504	-196,242	-191,796	-6,845,316	7,134,987
2016	5,614	4,442	611	554	16,504	-5,514	-2,081,602	-1,851,717	-242,043	-219,688	-6,879,543	7,213,472
2017	5,909	4,487	731	628	16,670	-5,575	-2,135,723	-1,860,975	-288,297	-247,854	-6,913,940	7,292,820
2018	6,209	4,532	896	739	16,837	-5,636	-2,189,116	-1,870,280	-343,341	-283,169	-6,948,510	7,373,041
2019	6,510	4,577	1,077	860	17,006	-5,698	-2,241,655	-1,879,632	-401,039	-320,069	-6,983,253	7,454,144
2020	6,813	4,623	1,274	990	17,176	-5,761	-2,293,213	-1,889,030	-461,345	-358,523	-7,018,169	7,536,140
2021	7,116	4,670	1,487	1,130	17,348	-5,824	-2,343,664	-1,898,475	-524,203	-398,491	-7,053,260	7,619,038
2022	7,404	4,716	1,716	1,280	17,522	-5,888	-2,390,537	-1,907,967	-589,545	-439,927	-7,088,526	7,702,847
2023	7,703	4,764	1,961	1,440	17,698	-5,953	-2,438,348	-1,917,507	-657,290	-482,777	-7,123,969	7,787,578
2024	8,014	4,811	2,222	1,610	17,875	-6,019	-2,487,115	-1,927,095	-727,342	-526,980	-7,159,588	7,873,242
2025	8,338	4,860	2,499	1,789	18,054	-6,085	-2,536,857	-1,936,730	-799,597	-572,467	-7,195,386	7,959,847
2026	8,675	4,908	2,791	1,977	18,235	-6,152	-2,587,594	-1,946,414	-873,936	-619,163	-7,231,363	8,047,406
2027	9,025	4,958	3,092	2,171	18,418	-6,219	-2,639,346	-1,956,146	-949,297	-666,329	-7,267,520	8,135,927
2028	9,390	5,007	3,413	2,376	18,603	-6,288	-2,692,133	-1,965,926	-1,027,324	-715,134	-7,303,858	8,225,422
2029	9,769	5,057	3,755	2,595	18,789	-6,357	-2,745,976	-1,975,756	-1,108,091	-765,625	-7,340,377	8,315,902
2030	10,164	5,108	4,119	2,827	18,978	-6,427	-2,800,895	-1,985,635	-1,191,679	-817,849	-7,377,079	8,407,377
2031	10,574	5,159	4,507	3,074	19,168	-6,498	-2,856,913	-1,995,563	-1,278,166	-871,856	-7,413,964	8,499,858
2032	11,002	5,211	4,919	3,336	19,360	-6,569	-2,914,051	-2,005,541	-1,367,637	-927,696	-7,451,034	8,593,356
2033	11,446	5,263	5,357	3,615	19,554	-6,641	-2,972,332	-2,015,569	-1,460,175	-985,421	-7,488,289	8,687,883
2034	11,908	5,316	5,822	3,910	19,750	-6,714	-3,031,779	-2,025,646	-1,555,867	-1,045,084	-7,525,731	8,783,450

Source: Author’s calculation

Table A3 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *Half Convergence* when there is *No Genetic Protection* for Canadian Red Lentils, 2011-2034

Half Convergences - No Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,648	-78,875	-6,710,104	6,829,495
2012	4,492	4,269	93	224	15,859	-5,278	-1,862,100	-1,815,141	-38,756	-92,789	-6,743,655	6,904,619
2013	4,766	4,311	154	267	16,018	-5,336	-1,917,962	-1,824,216	-62,158	-107,386	-6,777,373	6,980,570
2014	5,046	4,355	222	314	16,178	-5,395	-1,973,583	-1,833,337	-86,846	-122,656	-6,811,260	7,057,356
2015	5,333	4,398	297	364	16,340	-5,454	-2,028,844	-1,842,504	-112,803	-138,587	-6,845,316	7,134,987
2016	5,625	4,442	378	419	16,504	-5,514	-2,083,623	-1,851,717	-140,009	-155,162	-6,879,543	7,213,472
2017	5,921	4,487	467	477	16,670	-5,575	-2,137,797	-1,860,975	-168,439	-172,363	-6,913,940	7,292,820
2018	6,221	4,532	562	540	16,837	-5,636	-2,191,242	-1,870,280	-198,058	-190,169	-6,948,510	7,373,041
2019	6,523	4,577	665	606	17,006	-5,698	-2,243,831	-1,879,632	-228,830	-208,553	-6,983,253	7,454,144
2020	6,826	4,623	775	677	17,176	-5,761	-2,295,440	-1,889,030	-260,710	-227,488	-7,018,169	7,536,140
2021	7,130	4,670	892	751	17,348	-5,824	-2,345,939	-1,898,475	-293,648	-246,942	-7,053,260	7,619,038
2022	7,418	4,716	1,015	827	17,522	-5,888	-2,392,858	-1,907,967	-327,267	-266,619	-7,088,526	7,702,847
2023	7,718	4,764	1,145	907	17,698	-5,953	-2,440,715	-1,917,507	-362,114	-286,984	-7,123,969	7,787,578
2024	8,030	4,811	1,284	994	17,875	-6,019	-2,489,529	-1,927,095	-398,224	-308,058	-7,159,588	7,873,242
2025	8,354	4,860	1,433	1,085	18,054	-6,085	-2,539,320	-1,936,730	-435,633	-329,859	-7,195,386	7,959,847
2026	8,692	4,908	1,592	1,183	18,235	-6,152	-2,590,106	-1,946,414	-474,380	-352,409	-7,231,363	8,047,406
2027	9,043	4,958	1,761	1,286	18,418	-6,219	-2,641,909	-1,956,146	-514,502	-375,729	-7,267,520	8,135,927
2028	9,408	5,007	1,941	1,396	18,603	-6,288	-2,694,747	-1,965,926	-556,039	-399,842	-7,303,858	8,225,422
2029	9,788	5,057	2,133	1,513	18,789	-6,357	-2,748,642	-1,975,756	-599,031	-424,768	-7,340,377	8,315,902
2030	10,184	5,108	2,337	1,636	18,978	-6,427	-2,803,615	-1,985,635	-643,521	-450,531	-7,377,079	8,407,377
2031	10,595	5,159	2,555	1,768	19,168	-6,498	-2,859,687	-1,995,563	-689,552	-477,156	-7,413,964	8,499,858
2032	11,023	5,211	2,786	1,907	19,360	-6,569	-2,916,881	-2,005,541	-737,165	-504,664	-7,451,034	8,593,356
2033	11,468	5,263	3,031	2,055	19,554	-6,641	-2,975,218	-2,015,569	-786,408	-533,083	-7,488,289	8,687,883
2034	11,932	5,316	3,292	2,211	19,750	-6,714	-3,034,723	-2,025,646	-837,325	-562,436	-7,525,731	8,783,450

Source: Author’s calculation

Table A4 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *Half Convergence* when there is *Genetic Protection* for Canadian Red Lentils, 2011-2034

Half Convergences - Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,648	-78,875	-6,710,104	6,829,495
2012	4,492	4,269	93	223	15,859	-5,278	-1,862,100	-1,815,141	-38,718	-92,699	-6,743,655	6,904,619
2013	4,766	4,311	154	267	16,018	-5,336	-1,917,962	-1,824,216	-62,158	-107,386	-6,777,373	6,980,570
2014	5,046	4,355	212	299	16,178	-5,395	-1,973,583	-1,833,337	-84,820	-119,795	-6,811,260	7,057,356
2015	5,333	4,398	270	332	16,340	-5,454	-2,028,844	-1,842,504	-107,707	-132,326	-6,845,316	7,134,987
2016	5,625	4,442	330	366	16,504	-5,514	-2,083,623	-1,851,717	-130,821	-144,979	-6,879,543	7,213,472
2017	5,921	4,487	391	400	16,670	-5,575	-2,137,797	-1,860,975	-154,163	-157,755	-6,913,940	7,292,820
2018	6,221	4,532	476	457	16,837	-5,636	-2,191,242	-1,870,280	-182,156	-174,900	-6,948,510	7,373,041
2019	6,523	4,577	568	518	17,006	-5,698	-2,243,831	-1,879,632	-211,485	-192,745	-6,983,253	7,454,144
2020	6,826	4,623	669	584	17,176	-5,761	-2,295,440	-1,889,030	-242,126	-211,272	-7,018,169	7,536,140
2021	7,130	4,670	777	654	17,348	-5,824	-2,345,939	-1,898,475	-274,051	-230,462	-7,053,260	7,619,038
2022	7,418	4,716	894	728	17,522	-5,888	-2,392,858	-1,907,967	-307,223	-250,289	-7,088,526	7,702,847
2023	7,718	4,764	1,019	808	17,698	-5,953	-2,440,715	-1,917,507	-341,602	-270,728	-7,123,969	7,787,578
2024	8,030	4,811	1,152	891	17,875	-6,019	-2,489,529	-1,927,095	-377,139	-291,747	-7,159,588	7,873,242
2025	8,354	4,860	1,293	979	18,054	-6,085	-2,539,320	-1,936,730	-413,781	-313,313	-7,195,386	7,959,847
2026	8,692	4,908	1,442	1,071	18,235	-6,152	-2,590,106	-1,946,414	-451,468	-335,388	-7,231,363	8,047,406
2027	9,043	4,958	1,595	1,165	18,418	-6,219	-2,641,909	-1,956,146	-489,652	-357,582	-7,267,520	8,135,927
2028	9,408	5,007	1,758	1,264	18,603	-6,288	-2,694,747	-1,965,926	-529,183	-380,530	-7,303,858	8,225,422
2029	9,788	5,057	1,932	1,370	18,789	-6,357	-2,748,642	-1,975,756	-570,099	-404,252	-7,340,377	8,315,902
2030	10,184	5,108	2,117	1,482	18,978	-6,427	-2,803,615	-1,985,635	-612,440	-428,771	-7,377,079	8,407,377
2031	10,595	5,159	2,314	1,601	19,168	-6,498	-2,859,687	-1,995,563	-656,247	-454,110	-7,413,964	8,499,858
2032	11,023	5,211	2,523	1,727	19,360	-6,569	-2,916,881	-2,005,541	-701,561	-480,290	-7,451,034	8,593,356
2033	11,468	5,263	2,746	1,861	19,554	-6,641	-2,975,218	-2,015,569	-748,425	-507,335	-7,488,289	8,687,883
2034	11,932	5,316	2,982	2,003	19,750	-6,714	-3,034,723	-2,025,646	-796,884	-535,271	-7,525,731	8,783,450

Source: Author's calculation

Table A5 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *Quarter Convergence* when there is *No Genetic Protection* for Canadian Red Lentils, 2011-2034

Quarter Convergences - No Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,648	-78,875	-6,710,104	6,829,495
2012	4,492	4,269	67	206	15,859	-5,278	-1,862,100	-1,815,141	-27,729	-85,382	-6,743,655	6,904,619
2013	4,766	4,311	98	229	16,018	-5,336	-1,917,962	-1,824,216	-39,442	-92,128	-6,777,373	6,980,570
2014	5,046	4,355	132	253	16,178	-5,395	-1,973,583	-1,833,337	-51,784	-99,105	-6,811,260	7,057,356
2015	5,333	4,398	170	279	16,340	-5,454	-2,028,844	-1,842,504	-64,744	-106,305	-6,845,316	7,134,987
2016	5,625	4,442	211	307	16,504	-5,514	-2,083,623	-1,851,717	-78,314	-113,721	-6,879,543	7,213,472
2017	5,921	4,487	256	336	16,670	-5,575	-2,137,797	-1,860,975	-92,479	-121,341	-6,913,940	7,292,820
2018	6,221	4,532	304	367	16,837	-5,636	-2,191,242	-1,870,280	-107,224	-129,155	-6,948,510	7,373,041
2019	6,523	4,577	356	399	17,006	-5,698	-2,243,831	-1,879,632	-122,528	-137,149	-6,983,253	7,454,144
2020	6,826	4,623	411	432	17,176	-5,761	-2,295,440	-1,889,030	-138,369	-145,311	-7,018,169	7,536,140
2021	7,130	4,670	470	467	17,348	-5,824	-2,345,939	-1,898,475	-154,723	-153,626	-7,053,260	7,619,038
2022	7,418	4,716	531	502	17,522	-5,888	-2,392,858	-1,907,967	-171,394	-161,918	-7,088,526	7,702,847
2023	7,718	4,764	597	539	17,698	-5,953	-2,440,715	-1,917,507	-188,670	-170,481	-7,123,969	7,787,578
2024	8,030	4,811	666	578	17,875	-6,019	-2,489,529	-1,927,095	-206,568	-179,321	-7,159,588	7,873,242
2025	8,354	4,860	741	620	18,054	-6,085	-2,539,320	-1,936,730	-225,106	-188,447	-7,195,386	7,959,847
2026	8,692	4,908	820	664	18,235	-6,152	-2,590,106	-1,946,414	-244,304	-197,866	-7,231,363	8,047,406
2027	9,043	4,958	904	711	18,418	-6,219	-2,641,909	-1,956,146	-264,179	-207,587	-7,267,520	8,135,927
2028	9,408	5,007	994	760	18,603	-6,288	-2,694,747	-1,965,926	-284,752	-217,617	-7,303,858	8,225,422
2029	9,788	5,057	1,090	812	18,789	-6,357	-2,748,642	-1,975,756	-306,041	-227,965	-7,340,377	8,315,902
2030	10,184	5,108	1,192	867	18,978	-6,427	-2,803,615	-1,985,635	-328,069	-238,640	-7,377,079	8,407,377
2031	10,595	5,159	1,300	925	19,168	-6,498	-2,859,687	-1,995,563	-350,855	-249,651	-7,413,964	8,499,858
2032	11,023	5,211	1,415	986	19,360	-6,569	-2,916,881	-2,005,541	-374,422	-261,007	-7,451,034	8,593,356
2033	11,468	5,263	1,537	1,051	19,554	-6,641	-2,975,218	-2,015,569	-398,790	-272,718	-7,488,289	8,687,883
2034	11,932	5,316	1,667	1,120	19,750	-6,714	-3,034,723	-2,025,646	-423,984	-284,792	-7,525,731	8,783,450

Source: Author’s calculation

Table A6 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *Quarter Convergence* when there is *Genetic Protection* for Canadian Red Lentils, 2011-2034

Quarter Convergences - Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,648	-78,875	-6,710,104	6,829,495
2012	4,492	4,269	67	206	15,859	-5,278	-1,862,100	-1,815,141	-27,702	-85,299	-6,743,655	6,904,619
2013	4,766	4,311	98	229	16,018	-5,336	-1,917,962	-1,824,216	-39,442	-92,128	-6,777,373	6,980,570
2014	5,046	4,355	126	242	16,178	-5,395	-1,973,583	-1,833,337	-50,576	-96,793	-6,811,260	7,057,356
2015	5,333	4,398	155	255	16,340	-5,454	-2,028,844	-1,842,504	-61,820	-101,503	-6,845,316	7,134,987
2016	5,625	4,442	185	268	16,504	-5,514	-2,083,623	-1,851,717	-73,175	-106,258	-6,879,543	7,213,472
2017	5,921	4,487	215	282	16,670	-5,575	-2,137,797	-1,860,975	-84,641	-111,057	-6,913,940	7,292,820
2018	6,221	4,532	257	310	16,837	-5,636	-2,191,242	-1,870,280	-98,615	-118,785	-6,948,510	7,373,041
2019	6,523	4,577	304	341	17,006	-5,698	-2,243,831	-1,879,632	-113,240	-126,754	-6,983,253	7,454,144
2020	6,826	4,623	355	373	17,176	-5,761	-2,295,440	-1,889,030	-128,506	-134,953	-7,018,169	7,536,140
2021	7,130	4,670	410	407	17,348	-5,824	-2,345,939	-1,898,475	-144,398	-143,373	-7,053,260	7,619,038
2022	7,418	4,716	468	442	17,522	-5,888	-2,392,858	-1,907,967	-160,897	-152,001	-7,088,526	7,702,847
2023	7,718	4,764	531	480	17,698	-5,953	-2,440,715	-1,917,507	-177,982	-160,824	-7,123,969	7,787,578
2024	8,030	4,811	598	519	17,875	-6,019	-2,489,529	-1,927,095	-195,631	-169,827	-7,159,588	7,873,242
2025	8,354	4,860	668	559	18,054	-6,085	-2,539,320	-1,936,730	-213,815	-178,994	-7,195,386	7,959,847
2026	8,692	4,908	743	601	18,235	-6,152	-2,590,106	-1,946,414	-232,504	-188,309	-7,231,363	8,047,406
2027	9,043	4,958	819	644	18,418	-6,219	-2,641,909	-1,956,146	-251,420	-197,560	-7,267,520	8,135,927
2028	9,408	5,007	900	688	18,603	-6,288	-2,694,747	-1,965,926	-270,998	-207,106	-7,303,858	8,225,422
2029	9,788	5,057	987	735	18,789	-6,357	-2,748,642	-1,975,756	-291,260	-216,955	-7,340,377	8,315,902
2030	10,184	5,108	1,079	785	18,978	-6,427	-2,803,615	-1,985,635	-312,224	-227,114	-7,377,079	8,407,377
2031	10,595	5,159	1,177	838	19,168	-6,498	-2,859,687	-1,995,563	-333,909	-237,593	-7,413,964	8,499,858
2032	11,023	5,211	1,282	893	19,360	-6,569	-2,916,881	-2,005,541	-356,337	-248,401	-7,451,034	8,593,356
2033	11,468	5,263	1,392	952	19,554	-6,641	-2,975,218	-2,015,569	-379,529	-259,546	-7,488,289	8,687,883
2034	11,932	5,316	1,510	1,014	19,750	-6,714	-3,034,723	-2,025,646	-403,506	-271,037	-7,525,731	8,783,450

Source: Author’s calculation

Table A7 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *No Convergence* when there is *No Genetic Protection* for Canadian Red Lentils, 2011-2034

No Convergences - No Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,647	-78,875	-6,710,104	6,829,494
2012	4,492	4,269	41	196	15,859	-5,278	-1,862,100	-1,815,141	-17,147	-81,241	-6,743,655	6,904,619
2013	4,766	4,311	44	208	16,018	-5,336	-1,917,962	-1,824,216	-17,678	-83,760	-6,777,373	6,980,570
2014	5,046	4,355	47	221	16,178	-5,395	-1,973,583	-1,833,337	-18,209	-86,273	-6,811,260	7,057,356
2015	5,333	4,398	49	234	16,340	-5,454	-2,028,844	-1,842,504	-18,737	-88,775	-6,845,316	7,134,987
2016	5,625	4,442	52	247	16,504	-5,514	-2,083,623	-1,851,717	-19,262	-91,260	-6,879,543	7,213,472
2017	5,921	4,487	55	261	16,670	-5,575	-2,137,797	-1,860,975	-19,782	-93,724	-6,913,940	7,292,820
2018	6,221	4,532	58	274	16,837	-5,636	-2,191,242	-1,870,280	-20,296	-96,161	-6,948,510	7,373,041
2019	6,523	4,577	61	288	17,006	-5,698	-2,243,831	-1,879,632	-20,803	-98,565	-6,983,253	7,454,144
2020	6,826	4,623	64	302	17,176	-5,761	-2,295,440	-1,889,030	-21,303	-100,931	-7,018,169	7,536,140
2021	7,130	4,670	67	316	17,348	-5,824	-2,345,939	-1,898,475	-21,793	-103,252	-7,053,260	7,619,037
2022	7,418	4,716	70	330	17,522	-5,888	-2,392,858	-1,907,967	-22,272	-105,524	-7,088,526	7,702,847
2023	7,718	4,764	73	344	17,698	-5,953	-2,440,715	-1,917,507	-22,717	-107,634	-7,123,969	7,787,578
2024	8,030	4,811	75	358	17,875	-6,019	-2,489,529	-1,927,095	-23,172	-109,787	-7,159,588	7,873,241
2025	8,354	4,860	79	372	18,054	-6,085	-2,539,320	-1,936,730	-23,635	-111,983	-7,195,386	7,959,847
2026	8,692	4,908	82	387	18,235	-6,152	-2,590,106	-1,946,414	-24,108	-114,222	-7,231,363	8,047,405
2027	9,043	4,958	85	403	18,418	-6,219	-2,641,909	-1,956,146	-24,590	-116,507	-7,267,520	8,135,927
2028	9,408	5,007	88	419	18,603	-6,288	-2,694,747	-1,965,926	-25,082	-118,837	-7,303,858	8,225,422
2029	9,788	5,057	92	436	18,789	-6,357	-2,748,642	-1,975,756	-25,583	-121,213	-7,340,377	8,315,902
2030	10,184	5,108	96	453	18,978	-6,427	-2,803,615	-1,985,635	-26,095	-123,638	-7,377,079	8,407,377
2031	10,595	5,159	100	472	19,168	-6,498	-2,859,687	-1,995,563	-26,617	-126,110	-7,413,964	8,499,858
2032	11,023	5,211	104	491	19,360	-6,569	-2,916,881	-2,005,541	-27,149	-128,633	-7,451,034	8,593,356
2033	11,468	5,263	108	511	19,554	-6,641	-2,975,218	-2,015,569	-27,692	-131,205	-7,488,289	8,687,883
2034	11,932	5,316	112	531	19,750	-6,714	-3,034,723	-2,025,646	-28,246	-133,829	-7,525,731	8,783,450

Source: Author’s calculation

Table A8 Slopes and Intercepts for Canada, Russia, Kazakhstan, ROW and World Demand with *No Convergence* when there is *Genetic Protection* for Canadian Red Lentils, 2011-2034

No Convergences - Genetic Protection												
	Slopes						**Intercepts**					
Year	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**	**Cdn Red**	**Cdn Green**	**Kaz**	**Rus**	**Row**	**Demand**
2011	4,226	4,226	39	185	15,701	-5,221	-1,806,110	-1,806,110	-16,647	-78,875	-6,710,104	6,829,494
2012	4,492	4,269	41	196	15,859	-5,278	-1,862,100	-1,815,141	-17,147	-81,241	-6,743,655	6,904,619
2013	4,766	4,311	44	208	16,018	-5,336	-1,917,962	-1,824,216	-17,678	-83,760	-6,777,373	6,980,570
2014	5,046	4,355	44	210	16,178	-5,395	-1,973,583	-1,833,337	-17,767	-84,179	-6,811,260	7,057,356
2015	5,333	4,398	45	212	16,340	-5,454	-2,028,844	-1,842,504	-17,856	-84,600	-6,845,316	7,134,987
2016	5,625	4,442	45	214	16,504	-5,514	-2,083,623	-1,851,717	-17,945	-85,023	-6,879,543	7,213,472
2017	5,921	4,487	46	217	16,670	-5,575	-2,137,797	-1,860,975	-18,035	-85,448	-6,913,940	7,292,820
2018	6,221	4,532	49	230	16,837	-5,636	-2,191,242	-1,870,280	-18,576	-88,011	-6,948,510	7,373,041
2019	6,523	4,577	51	243	17,006	-5,698	-2,243,831	-1,879,632	-19,114	-90,563	-6,983,253	7,454,144
2020	6,826	4,623	54	257	17,176	-5,761	-2,295,440	-1,889,030	-19,650	-93,099	-7,018,169	7,536,140
2021	7,130	4,670	57	271	17,348	-5,824	-2,345,939	-1,898,475	-20,180	-95,613	-7,053,260	7,619,037
2022	7,418	4,716	60	285	17,522	-5,888	-2,392,858	-1,907,967	-20,705	-98,099	-7,088,526	7,702,847
2023	7,718	4,764	63	300	17,698	-5,953	-2,440,715	-1,917,507	-21,222	-100,551	-7,123,969	7,787,578
2024	8,030	4,811	66	315	17,875	-6,019	-2,489,529	-1,927,095	-21,732	-102,964	-7,159,588	7,873,241
2025	8,354	4,860	69	329	18,054	-6,085	-2,539,320	-1,936,730	-22,232	-105,333	-7,195,386	7,959,847
2026	8,692	4,908	73	344	18,235	-6,152	-2,590,106	-1,946,414	-22,721	-107,650	-7,231,363	8,047,405
2027	9,043	4,958	75	358	18,418	-6,219	-2,641,909	-1,956,146	-23,175	-109,803	-7,267,520	8,135,927
2028	9,408	5,007	79	372	18,603	-6,288	-2,694,747	-1,965,926	-23,639	-111,999	-7,303,858	8,225,422
2029	9,788	5,057	82	387	18,789	-6,357	-2,748,642	-1,975,756	-24,111	-114,239	-7,340,377	8,315,902
2030	10,184	5,108	85	403	18,978	-6,427	-2,803,615	-1,985,635	-24,594	-116,524	-7,377,079	8,407,377
2031	10,595	5,159	88	419	19,168	-6,498	-2,859,687	-1,995,563	-25,086	-118,854	-7,413,964	8,499,858
2032	11,023	5,211	92	436	19,360	-6,569	-2,916,881	-2,005,541	-25,587	-121,231	-7,451,034	8,593,356
2033	11,468	5,263	96	454	19,554	-6,641	-2,975,218	-2,015,569	-26,099	-123,656	-7,488,289	8,687,883
2034	11,932	5,316	100	472	19,750	-6,714	-3,034,723	-2,025,646	-26,621	-126,129	-7,525,731	8,783,450

Source: Author's calculation

Appendix B

The survey that was given to lentil experts in the lentil industry.

I am looking into the future development of production on lentils in Kazakhstan and Russia for my master's thesis. I have chosen the time period of 2014 to 2034 to examine the lentil industry. I have run some possible scenarios of what production in Kazakhstan and Russia could potential grow towards in the near future. Based on what you know about Russia and Kazakhstan and the scenarios that are described in the attachment, what probabilities would you place on each development scenario?

Overview-Future20 year growth Scenarios

In 2011 red lentil seeded area in Canada was 5% of the spring wheat area. At prevailing prices and yield many Canadian farmers find red lentils a profitable crop and have included it in their crop rotations. Although Russia and Kazakhstan have a large spring wheat area agronomically well suited to Canadian red lentil varieties, they both have very small, largely under developed lentil industry. One would expect that given the similar growing conditions and global market place, these countries will eventually recognise lentils as a valuable crop and converge toward Canada's position in these markets. The extent that producers in these countries will adopt lentils as crop in the future will depend on a number of factors including, prices, varieties, and the development of; farm agronomic expertise, improved grain handling and storage, improved grain transportation system, and an effective marketing system.

As an expert I need you to provide your assessment of future growth scenarios over the next twenty years. In my economic model I will include the impact of future variety improvements and price changes. I would like you to consider the situation where *current prices prevail* and *variety yields stay the same*. In other words, if all grain prices are the same as they are today Russia and Kazakhstan had full access to our current varieties how much of their spring wheat area would be seeded to lentils in the year 2034? To answer this question I have attached a chart at the end of the information I have provided.

To simplify, the range of possibilities I ask you to consider four scenarios and indicate your subjective probability that each scenario will be realized:

- **Scenario 1** (**No Convergence)** lentil production in Russia and Kazakhstan continues to stagnate over the next twenty years exhibiting no growth in lentil area between now and 2034.
- **Scenario 2 (Full Convergence)** Russia and Kazakhstan both converge to Canada's propensity to grow lentils over the next twenty years and would seed 5% of their spring wheat area to red lentils at today's prices and yields.
- **Scenario 3 (Half Convergence)** Russia and Kazakhstan both converge to one half of the Canadian intensity reaching 2.5% of spring wheat area by 2034.
- **Scenario 4 (Quarter Convergence)** Russia and Kazakhstan both converge to one quarter of the Canadian intensity reaching 1.25% of spring wheat area by 2034.

The term convergence is used to explain the future expansion of lentil production for Kazakhstan and Russia from 2014 to 2034 because in the scenarios provided the area that lentils will be grown on will catch-up to the amount of area that Canada grows lentils. In the three scenario, when Kazakhstan and Russia convergence to Canada's level of lentil production full, half and a quarter of the way, the amount of area that Canada, Kazakhstan and Russia plant lentil will not be the same but it will be based on the percentage of lentils to spring wheat hectares.

Here are two tables, which shows the hectares used to grow lentil for all four scenarios, and a figure for each Kazakhstan and Russia which graphs the four scenarios growth in the lentils industry.

Table B1 Lentil hectares and Percentage of Lentils to Spring Wheat Hectares for Canada, Kazakhstan and Russia for 2034

		Canada	Kazakhstan	Russia
Current (2011)	**Spring Wheat (ha)**	8,543,600	12,324,600	8,278,500
	Lentils area (ha)	998,400	0	47,578
	Red Lentil area (ha)	499,200		
	% of Wheat area	5%	0.00%	0.57%
Scenario 1 - No Convergence	**Red Lentil Area, 2034 (ha)**	499,200	10,042	47,578
	% of Wheat Area	5%	0.08%	0.57%
Scenario 2 - Full Convergence	**Red Lentil Area, 2034 (ha)**	499,200	586,897	394,222
	% of Wheat Area	5%	5%	5%
Scenario 3 - Half Convergence	**Red Lentil Area, 2034 (ha)**	499,200	300,597	201,913
	% of Wheat Area	5%	2.5%	2.5%
Scenario 4 - Quarter Convergence	**Red Lentil Area, 2034 (ha)**	499,200	152,209	102,239
	% of Wheat Area	5%	1.25%	1.25%

Source: FAOSTAT, 2012a; Author's calculation

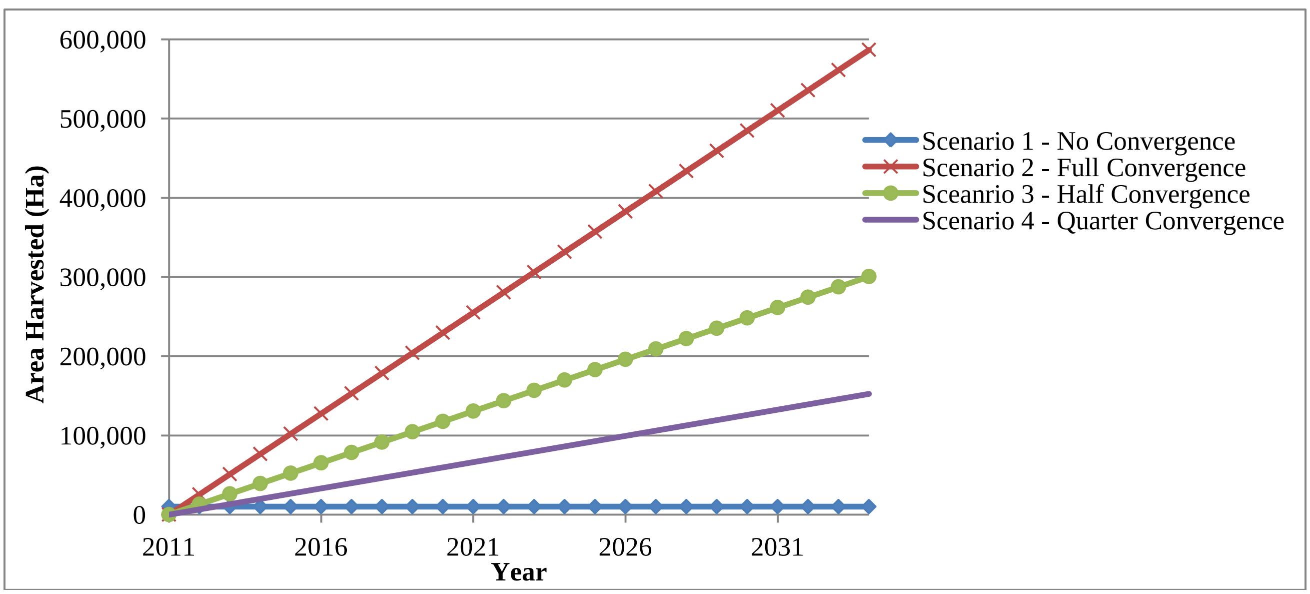

Figure B1 Four Scenario's of Lentil Hectares Harvested in Kazakhstan, 2011-2034
Source: Author's calculation

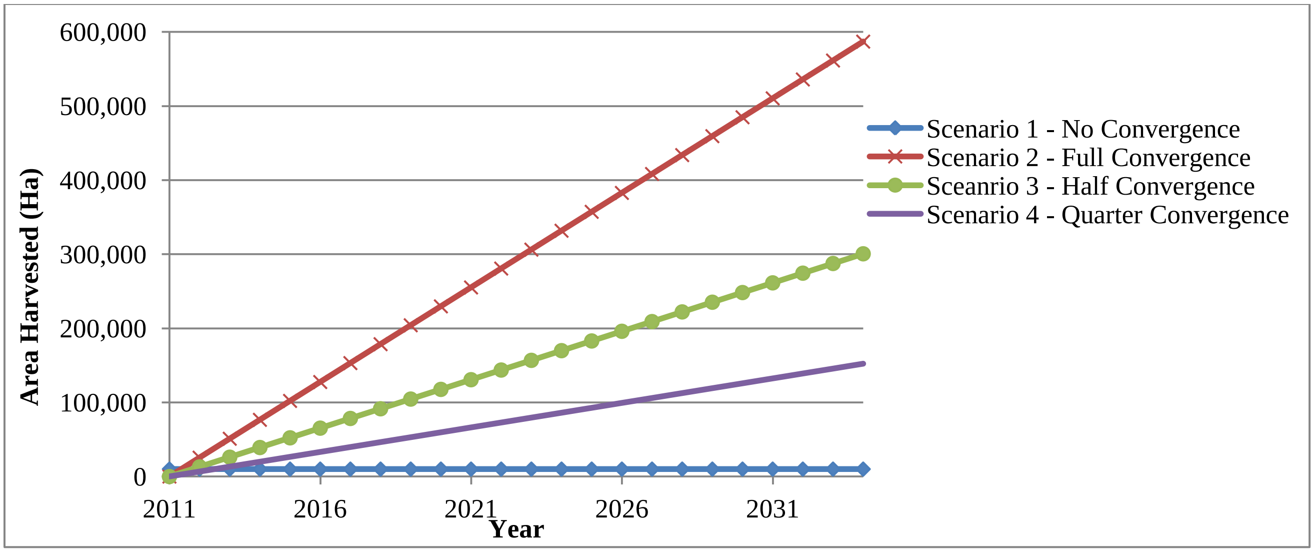

Figure B2 Four Scenario's for Lentil Hectares Harvested in Russia, 2011-2034
Source: Author's calculation

Table B2 Possible scenarios for the hectares of lentils grown in Kazakhstan and Russia, 2014-2034

	Scenario 1 - *No Convergence*		Scenario 2 - *Full Convergence*		Sceanrio 3 - *Half Convergence*		Scenario 4 - *Quarter Convergence*	
Year	**Kazakhstan**	**Russia**	**Kazakhstan**	**Russia**	**Kazakhstan**	**Russia**	**Kazakhstan**	**Russia**
2011	10,042	47,578	0	47,578	0	47,578	0	47,578
2012	10,042	47,578	25,517	62,649	13,069	54,288	6,618	49,954
2013	10,042	47,578	51,035	77,721	26,139	60,998	13,236	52,331
2014	10,042	47,578	76,552	92,792	39,208	67,708	19,853	54,708
2015	10,042	47,578	102,069	107,864	52,278	74,419	26,471	57,084
2016	10,042	47,578	127,586	122,935	65,347	81,129	33,089	59,461
2017	10,042	47,578	153,104	138,007	78,417	87,839	39,707	61,837
2018	10,042	47,578	178,621	153,078	91,486	94,549	46,324	64,214
2019	10,042	47,578	204,138	168,150	104,555	101,260	52,942	66,591
2020	10,042	47,578	229,656	183,221	117,625	107,970	59,560	68,967
2021	10,042	47,578	255,173	198,293	130,694	114,680	66,178	71,344
2022	10,042	47,578	280,690	213,364	143,764	121,390	72,796	73,720
2023	10,042	47,578	306,207	228,436	156,833	128,100	79,413	76,097
2024	10,042	47,578	331,725	243,507	169,903	134,811	86,031	78,474
2025	10,042	47,578	357,242	258,579	182,972	141,521	92,649	80,850
2026	10,042	47,578	382,759	273,650	196,042	148,231	99,267	83,227
2027	10,042	47,578	408,276	288,722	209,111	154,941	105,884	85,603
2028	10,042	47,578	433,794	303,793	222,180	161,651	112,502	87,980
2029	10,042	47,578	459,311	318,865	235,250	168,362	119,120	90,357
2030	10,042	47,578	484,828	333,936	248,319	175,072	125,738	92,733
2031	10,042	47,578	510,346	349,008	261,389	181,782	132,355	95,110
2032	10,042	47,578	535,863	364,079	274,458	188,492	138,973	97,486
2033	10,042	47,578	561,380	379,151	287,528	195,202	145,591	99,863
2034	10,042	47,578	586,897	394,222	300,597	201,913	152,209	102,239

[7]Source: Author's calculation

[7] In the simulation Kazakhstan produced 10,042 tonnes of lentils in 2011 for all four scenarios

Please indicate the probability that you would place on the scenarios to occur. The probabilities will have to equal 100% for each column, an example is provided.

		Probability of the Scenario Occurring	
		Kazakhstan & Russia	**Example**
Scenario 1	**No Convergence**		**25%**
Scenario 2	**Full Convergence**		**25%**
Scenario 3	**Half Convergence**		**25%**
Scenario 4	**Quarter Convergence**		**25%**
	Total	**100%**	**25+25+25+25=100**

Appendix C

Table C1 Russia and Kazakhstan's Lentil Production for the *Half Convergence* Scenario, 2014-2034

Half Convergence	*No Genetic Protection*		*Genetic Protection*		*Impact of Genetic Protection*	
Tonnes	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**
Year	**Russia**	**Kaz.**	**Russia**	**Kaz.**	**Russia**	**Kaz.**
2011	33.45	7.06	33.45	7.06	0.00	0.00
2012	43.45	18.15	43.27	18.07	0.17	0.07
2013	55.01	31.84	55.01	31.84	0.00	0.00
2014	68.21	48.30	62.27	44.09	5.94	4.21
2015	83.11	67.65	69.79	56.81	13.32	10.84
2016	99.75	90.01	77.58	70.00	22.18	20.01
2017	118.18	115.48	85.62	83.67	32.55	31.81
2018	138.40	144.14	103.02	107.30	35.37	36.84
2019	160.42	176.02	122.42	134.32	38.01	41.70
2020	184.25	211.15	143.86	164.86	40.39	46.29
2021	209.84	249.52	167.38	199.04	42.45	50.48
2022	236.42	290.20	193.02	236.92	43.40	53.28
2023	265.31	334.76	220.77	278.56	44.54	56.20
2024	296.64	383.47	250.62	323.97	46.03	59.50
2025	330.59	436.60	282.54	373.14	48.05	63.46
2026	367.30	494.43	316.48	426.01	50.82	68.41
2027	406.95	557.26	351.32	481.08	55.63	76.18
2028	449.73	625.41	388.95	540.90	60.77	84.51
2029	495.81	699.22	429.55	605.78	66.26	93.45
2030	545.42	779.05	473.29	676.03	72.12	103.02
2031	598.74	865.26	520.37	752.00	78.37	113.26
2032	656.02	958.25	570.98	834.04	85.04	124.21
2033	717.48	1,058.43	625.34	922.51	92.14	135.92
2034	783.38	1,166.25	683.68	1,017.83	99.70	148.43

Source: Author's calculation

Table C2 Russia and Kazakhstan's Lentil Production for the *Quarter Convergence* Scenario, 2014-2034

Quarter Convergence	*No Genetic Protection*		*Genetic Protection*		*Impact of Genetic Protection*	
Tonnes	**000'**	**000'**	**000'**	**000'**	**000'**	**000'**
Year	**Russia**	**Kaz.**	**Russia**	**Kaz.**	**Russia**	**Kaz.**
2011	33.45	7.06	33.45	7.06	0.00	0.00
2012	39.98	12.98	39.82	12.93	0.16	0.05
2013	47.20	20.21	47.20	20.21	0.00	0.00
2014	55.12	28.80	50.32	26.29	4.80	2.51
2015	63.75	38.83	53.54	32.61	10.22	6.22
2016	73.11	50.35	56.86	39.15	16.26	11.19
2017	83.19	63.41	60.28	45.94	22.92	17.47
2018	93.99	78.03	69.97	58.09	24.02	19.95
2019	105.50	94.25	80.50	71.92	24.99	22.33
2020	117.69	112.07	91.89	87.50	25.80	24.57
2021	130.54	131.47	104.13	104.87	26.41	26.60
2022	143.58	151.98	117.22	124.08	26.36	27.90
2023	157.60	174.42	131.14	145.14	26.46	29.28
2024	172.68	198.92	145.88	168.05	26.79	30.86
2025	188.86	225.60	161.41	192.81	27.45	32.79
2026	206.23	254.63	177.69	219.40	28.54	35.23
2027	224.84	286.13	194.10	247.02	30.74	39.12
2028	244.77	320.28	211.69	277.00	33.08	43.28
2029	266.09	357.23	230.53	309.49	35.56	47.74
2030	288.90	397.16	250.70	344.64	38.20	52.52
2031	313.27	440.26	272.26	382.63	41.01	57.63
2032	339.29	486.72	295.31	423.62	43.98	63.09
2033	367.05	536.74	319.92	467.81	47.14	68.93
2034	396.67	590.54	346.18	515.38	50.48	75.16

Source: Author's calculation

Table C3 Lentil Price Impacts in the Half Convergence Scenario and the Quarter Convergence Scenario, 2014-2034

	Half Convergence			***Quarter Convergence***		
	No Genetic Protection	***Genetic Protection***	**Impact of *GP***	***No Genetic Protection***	***Genetic Protection***	**Impact of *GP***
Year	**Price $/tonne**	**Price $/tonne**	**Price Affects $/tonne**	**Price $/tonne**	**Price $/tonne**	**Price Affects $/tonne**
2014	567.60	567.89	0.29	568.45	568.66	0.21
2015	562.44	563.11	0.67	563.64	564.10	0.46
2016	557.25	558.37	1.13	558.84	559.58	0.74
2017	552.03	553.70	1.67	554.05	555.11	1.06
2018	546.83	548.63	1.81	549.30	550.42	1.12
2019	541.64	543.57	1.93	544.59	545.76	1.17
2020	536.49	538.52	2.03	539.95	541.15	1.21
2021	531.40	533.50	2.10	535.38	536.61	1.23
2022	526.56	528.68	2.12	531.07	532.29	1.23
2023	521.64	523.78	2.14	526.70	527.92	1.23
2024	516.64	518.81	2.16	522.26	523.50	1.23
2025	511.57	513.78	2.21	517.77	519.02	1.25
2026	506.41	508.70	2.28	513.23	514.51	1.28
2027	501.18	503.62	2.44	508.62	509.98	1.36
2028	495.88	498.47	2.59	503.96	505.40	1.44
2029	490.50	493.26	2.75	499.23	500.76	1.53
2030	485.06	487.97	2.91	494.46	496.07	1.61
2031	479.55	482.62	3.07	489.63	491.32	1.70
2032	473.97	477.20	3.23	484.74	486.52	1.78
2033	468.34	471.72	3.38	479.80	481.67	1.87
2034	462.64	466.18	3.54	474.81	476.77	1.96

Source: Author's calculation

Table C4 Canadian Lentil Production Impacts in the *Half Convergence* Scenario and the *Quarter Convergence* Scenario, 2014-2034

	Half Convergence			***Quarter Convergence***		
	No Genetic Protection	***Genetic Protection***	**Impact of *GP***	***No Genetic Protection***	***Genetic Protection***	**Impact of *GP***
Year	**Tonnes (000'000')**	**Tonnes (000'000')**	**Tonnes (000')**	**Tonnes (000'000')**	**Tonnes (000'000')**	**Tonnes (000')**
2014	1.53	1.53	2.73	1.54	1.54	1.98
2015	1.60	1.61	6.50	1.61	1.62	4.46
2016	1.67	1.69	11.36	1.69	1.70	7.48
2017	1.75	1.76	17.33	1.77	1.78	11.03
2018	1.82	1.84	19.43	1.84	1.86	12.04
2019	1.89	1.91	21.41	1.92	1.93	12.98
2020	1.96	1.98	23.22	2.00	2.01	13.83
2021	2.03	2.05	24.82	2.07	2.09	14.56
2022	2.09	2.11	25.71	2.14	2.16	14.89
2023	2.15	2.18	26.67	2.22	2.23	15.29
2024	2.22	2.25	27.79	2.29	2.31	15.80
2025	2.28	2.31	29.21	2.37	2.38	16.49
2026	2.35	2.38	31.06	2.44	2.46	17.44
2027	2.42	2.45	34.14	2.52	2.54	19.07
2028	2.49	2.52	37.40	2.60	2.62	20.82
2029	2.56	2.60	40.85	2.69	2.71	22.67
2030	2.63	2.67	44.49	2.77	2.80	24.64
2031	2.70	2.75	48.32	2.86	2.89	26.73
2032	2.77	2.82	52.36	2.95	2.98	28.94
2033	2.85	2.90	56.60	3.04	3.07	31.28
2034	2.92	2.98	61.06	3.13	3.16	33.76

Source: Author's calculation

Table C5 Annual Canadian Welfare Impacts in the *Half Convergence* Scenario and the *Quarter Convergence* Scenario, 2014-2034

	Half Convergence			***Quarter Convergence***		
	No Genetic Protection	***Genetic Protection***	**Impact of GP**	***No Genetic Protection***	***Genetic Protection***	**Impact of GP**
	(000'000')	**(000'000')**	**(000')**	**(000'000')**	**(000'000')**	**(000')**
Year	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**
2014	118.43	118.85	422.72	119.66	119.97	308.06
2015	119.58	120.55	972.59	121.33	122.00	672.38
2016	120.30	121.93	1,638.01	122.61	123.70	1,087.37
2017	120.58	122.99	2,405.16	123.51	125.05	1,546.47
2018	120.45	123.04	2,588.03	124.01	125.63	1,623.71
2019	119.92	122.65	2,733.87	124.12	125.80	1,682.22
2020	119.00	121.84	2,839.29	123.85	125.58	1,720.41
2021	117.71	120.61	2,901.88	123.23	124.97	1,737.11
2022	115.88	118.75	2,870.06	122.02	123.72	1,701.76
2023	113.96	116.80	2,840.78	120.73	122.41	1,672.12
2024	111.96	114.78	2,823.96	119.36	121.02	1,653.18
2025	109.88	112.71	2,829.32	117.91	119.56	1,649.92
2026	107.73	110.59	2,866.20	116.39	118.06	1,667.21
2027	105.51	108.51	3,000.04	114.79	116.54	1,742.46
2028	103.24	106.37	3,127.88	113.13	114.94	1,816.00
2029	100.91	104.16	3,249.30	111.40	113.28	1,887.61
2030	98.53	101.90	3,363.94	109.60	111.56	1,957.09
2031	96.12	99.59	3,471.45	107.75	109.77	2,024.27
2032	93.66	97.23	3,571.52	105.84	107.93	2,088.94
2033	91.18	94.84	3,663.89	103.88	106.04	2,150.93
2034	88.67	92.42	3,748.33	101.88	104.09	2,210.07

Source: Author’s calculation

Table C6 Net Total Canadian Welfare Impacts in the *Full Convergence* Scenario and the *No Convergence* Scenario, 2014-2034

	Half Convergence			***Quarter Convergence***		
	No Genetic Protection	***Genetic Protection***	**Impact of *GP***	***No Genetic Protection***	***Genetic Protection***	**Impact of *GP***
	(000'000')	**(000'000')**	**(000'000')**	**(000'000')**	**(000'000')**	**(000'000')**
Year	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**	**Discounted PS Cdn$**
2014	118.43	118.85	0.42	119.66	119.97	0.31
2015	238.01	239.40	1.40	240.99	241.97	0.98
2016	358.30	361.33	3.03	363.60	365.67	2.07
2017	478.89	484.32	5.44	487.11	490.72	3.61
2018	599.34	607.37	8.03	611.11	616.35	5.24
2019	719.26	730.02	10.76	735.23	742.15	6.92
2020	838.25	851.85	13.60	859.09	867.73	8.64
2021	955.96	972.47	16.50	982.32	992.69	10.38
2022	1,071.84	1,091.21	19.37	1,104.34	1,116.42	12.08
2023	1,185.80	1,208.01	22.21	1,225.07	1,238.82	13.75
2024	1,297.76	1,322.79	25.04	1,344.44	1,359.84	15.40
2025	1,407.63	1,435.50	27.87	1,462.35	1,479.40	17.05
2026	1,515.36	1,546.09	30.73	1,578.74	1,597.46	18.72
2027	1,620.87	1,654.61	33.73	1,693.53	1,714.00	20.46
2028	1,724.11	1,760.97	36.86	1,806.66	1,828.94	22.28
2029	1,825.02	1,865.13	40.11	1,918.06	1,942.23	24.17
2030	1,923.56	1,967.03	43.47	2,027.66	2,053.79	26.13
2031	2,019.67	2,066.62	46.94	2,135.41	2,163.56	28.15
2032	2,113.33	2,163.85	50.52	2,241.26	2,271.49	30.24
2033	2,204.51	2,258.69	54.18	2,345.14	2,377.53	32.39
2034	2,293.18	2,351.11	57.93	2,447.02	2,481.62	34.60

Source: Author’s calculation

Table C7 Expected Economic Impacts of each Scenario for Canada, Russia, Kazakhstan, ROW and the Global Lentil Industry when Canadian Red Lentils are Protected Through *Genetic Protection* versus *No Genetic Protection*, 2014-2034

		No Genetic Protection	*Genetic Protection*	*Impact of GP*
Scenario	**Country**	**Discounted PS 2014-2034 Cdn$(000)**	**Discounted PS 2014-2034 Cdn$(000)**	**Discounted PS 2014-2034 Cdn$(000)**
***Full Convergence* (24%)**	**Canada**	493,684	516,155	22,471
	Russia	96,787	75,311	-21,476
	Kazakhstan	133,479	104,419	-29,060
	ROW	352,585	372,227	19,642
	World Producers	1,076,534	1,068,112	-8,422
	World Consumers	5,809,840	5,758,277	-51,563
***Half Convergence* (23%)**	**Canada**	533,164	546,632	13,468
	Russia	57,897	44,490	-13,407
	Kazakhstan	75,277	58,357	-16,919
	ROW	385,484	396,967	11,483
	World Producers	1,051,821	1,047,067	-4,754
	World Consumers	5,442,825	5,414,272	-28,553
***Quarter Convergence* (18%)**	**Canada**	428,228	434,283	6,055
	Russia	26,901	20,429	-6,471
	Kazakhstan	31,500	24,265	-7,235
	ROW	312,721	317,835	5,114
	World Producers	799,351	797,299	-2,051
	World Consumers	4,041,791	4,029,433	-12,359
***No Convergence* (35%)**	**Canada**	903,326	908,454	5,128
	Russia	35,074	25,280	-9,794
	Kazakhstan	7,403	5,336	-2,067
	ROW	665,234	670,309	5,075
	World Producers	1,611,038	1,609,379	-1,659
	World Consumers	7,992,652	7,982,266	-10,385

Source: Author's calculation